technical note technical note techn

High Altitude Proof of Concept Air Traffic Control Demonstration

Jerry Hadley
Simulation & Analysis Group, ACB-330

June 2004

DOT/FAA/CT-TN04/24

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

U.S. Department of Transportation
Federal Aviation Administration

William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN04/xx	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle High Altitude Proof of Concept Air Traffic Control Demonstration		**5. Report Date** June 2004 **6. Performing Organization Code** ACB-330
7. Author(s) Jerry Hadley, Simulation & Analysis Group, ACB-330		8. Performing Organization Report No.. DOT/FAA/CT-TN04/24
Performing Organization Name and Address Federal Aviation Administration NAS Simulation & Analysis Group, ACB-330 William J. Hughes Technical Center Atlantic City International Airport, NJ 08405		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address Federal Aviation Administration Air Traffic Airspace Management ATA-301 800 Independence Avenue S.W. Washington, D.C. 20591		**13. Type of Report and Period Covered** Technical Note **14. Sponsoring Agency Code** ATA-301
15. Supplementary Notes		

16. Abstract.

The present study examined several concepts that are being considered for implementation in the high altitude strata in the near future. The goal of this effort was to gather information from the participants and use their input to design a large-scale simulation to further investigate these concepts using site-specific airspace with various levels of traffic load. The culmination of the large-scale simulation will be to provide input on how these concepts may be implemented within the constraints of the existing NAS architecture

The High Altitude Airspace Concept outlines how one segment of the National Airspace System (NAS) could provide more of the freedoms described in the Free Flight initiative while permitting transparent operations for aircraft entering from and leaving to adjacent airspace. Operations conducted in this airspace would be along user-preferred routes from airspace entry to exit. The airspace would permit aircraft operations that are closer to optimum altitudes by increasing available flight levels (fls) through a reduction in vertical separation minima (RVSM) from 2,000 to 1,000 ft. The increase in available fls would also offer controllers more flexibility in managing conflicts rather than separating aircraft through structured route control. Reduced Required Navigation Performance (RNP) values to allow closer spacing of full Area Navigation (RNAV) routes would enable more aircraft to fly along beneficial routes while potentially decreasing the number of predicted conflicts a controller must manage.

The High Altitude Airspace Liaison design teams collectively developed airspace designed to enhance the NAS and improve system efficiency. Wherever possible, the design allows for non-restrictive routing, which is defined as airspace where users can plan and fly user-preferred routing. Where structured routing is required, the teams designed both RNAV and parallel RNAV routes (8 miles apart) and used other methods and procedures of making the airspace more efficient.

In an effort to fully understand the issues associated with controllers operating in this type of exclusionary airspace, the subgroup of the Airspace Liaison Team decided to conduct a proof of concept (POC). The POC, termed the High Altitude Demonstration, included both human-in-the-loop (HITL) simulation and some fast-time modeling. The HITL simulation, which is documented in this paper, focused primarily on identifying and understanding the impacts of these new procedures on en route controllers. Based upon the results of this demonstration, it is expected that follow-on simulations (both HITL and fast-time) will be needed to fully understand the benefits and impacts for both controllers and users.

17. Key Words Area Navigation, Reduced Vertical Separation Minima, High Altitude, Reduced Required Navigation Performance, real-time simulation		**18. Distribution Statement** This document is available to the public through the National Technical Information Service, Springfield, Virginia, 22161	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 64	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Table of Contents

List of Illustrations

Executive Summary

Today's National Airspace System (NAS) infrastructure and airspace design are constrained by various limitations. However, new technologies are allowing the Federal Aviation Administration (FAA) to move forward with beneficial changes. The move towards full implementation of Free Flight requires major alterations to the NAS infrastructure, avionics, decision support systems, and supporting procedures, all of which will take considerable time to implement.

As a step towards mature Free Flight, the Radio Technical Commission for Aeronautics, Inc. (RTCA) Select Committee is exploring the possibility of defining a high altitude airspace structure where the FAA could begin to implement many of the Free Flight concepts. This airspace would allow properly equipped users to begin achieving the economic benefits of flying their preferred routes and altitudes with fewer restrictions than the present system requires. The initial implementation would be exclusive for the higher flight levels (FLs) of the en route structure and introduced at additional lower levels as technology and procedures safely allow.

The High Altitude Airspace Concept defines how one segment of the NAS could provide more of the freedoms described in the Free Flight concept while permitting transparent operations for aircraft entering from and leaving to adjacent airspace. Operations conducted in this airspace would be along user-preferred routes from airspace entry to exit. The airspace would permit aircraft operations that are closer to optimum altitudes by increasing available FLs through a reduction in vertical separation minima (RVSM) from 2,000 to 1,000 ft. The increase in available FLs would also give controllers more flexibility in managing conflicts rather than separating aircraft through structured route control. Reduced Required Navigation Performance (RNP) values to allow closer spacing of full Area Navigation (RNAV) routes would enable more aircraft to fly along beneficial routes while potentially decreasing the number of predicted conflicts a controller must manage.

The High Altitude Concept Facility design teams collectively developed airspace designed to enhance the NAS and improve system efficiency. Wherever possible, the design allows for non-restrictive routing, which is defined as airspace where users can plan and fly user-preferred routing. Where structured routing is required, the teams designed both RNAV and parallel RNAV routes (8 miles apart) and used other methods and procedures of making the airspace more efficient.

In an effort to fully understand the issues associated with controllers operating in this type of exclusionary airspace, the subgroup of the Airspace Liaison Team decided to conduct some proof of concept (POC) work prior to the HAT. The POC, termed the High Altitude Demonstration, included both human-in-the-loop (HITL) simulation and some fast-time modeling. The HITL simulation focused primarily on identifying and understanding the impacts of these new procedures on en route controllers. Some preliminary data that may aid in subsequent assessments of the benefits and impacts of this exclusionary airspace on users were also collected during this simulation. It is expected that follow-on simulations (both HITL and fast-time) will be needed to fully understand the benefits and impacts for both controllers and users, based on the results of this initial demonstration.

The present study examined several concepts that are being considered for implementation in the high altitude strata in the very near future. The goal of this effort was to gather information from

the participants and use their input to design a large-scale simulation to further investigate these concepts using site-specific airspace with various levels of traffic load. The culmination of the large-scale effort will be to provide input on how these concepts (Navigational Reference System, tactical RVSM, and parallel RNAV routes) may be implemented within the constraints of the existing NAS architecture

1. INTRODUCTION

1.1 Background

In 1994, the Chairman of the Radio Technical Commission for Aeronautics, Inc. (RTCA) formed an RTCA Board of Directors' Select Committee on Free Flight tasked to reach consensus on a Free Flight concept. Free Flight is an innovative idea designed to enhance the safety and efficiency of the National Airspace System (NAS). The concept moves the NAS from a centralized command-and-control system between pilots and Certified Professional Controllers (CPCs) to a distributed system. This allows pilots, whenever practical, to choose their own route and file a flight plan that follows the most efficient and economical route.

Today's NAS infrastructure and airspace design are constrained by various limitations. However, new technologies are allowing the Federal Aviation Administration (FAA) to move forward with beneficial changes. The move towards full implementation of Free Flight requires major alterations to the NAS infrastructure, avionics, decision-support systems, and supporting procedures, all of which will take considerable time to implement.

As a step towards mature Free Flight, the RTCA Select Committee is exploring the possibility of defining a high altitude airspace structure where the FAA could begin to implement many of the Free Flight concepts. This airspace would allow properly equipped users to begin achieving the economic benefits of flying their preferred routes and altitudes with fewer restrictions than the present system requires. The initial implementation would be exclusive for the higher flight levels (FLs) of the en route structure and introduced at additional lower levels as technology and procedures safely allow.

The High Altitude Airspace Concept defines how one segment of the NAS could provide more of the freedoms described in the Free Flight concept while permitting transparent operations for aircraft entering and leaving adjacent airspace. Operations conducted in this airspace would be along user-preferred routes from airspace entry to exit. The airspace would permit aircraft operations that are closer to optimum altitudes by increasing available FLs through a reduction in vertical separation minima (RVSM) from 2,000 to 1,000 ft. The increase in available FLs would also give controllers more flexibility in managing conflicts rather than separating aircraft through structured route control. Reduced Required Navigation Performance (RNP) values to allow closer spacing of full Area Navigation (RNAV) routes would allow more aircraft to fly along beneficial routes while potentially decreasing the number of predicted conflicts a controller must manage.

1.2 Overview

Under the auspices of National Airspace Redesign, the subgroup of the Airspace Liaison Team (SALT) selected seven Air Route Traffic Control Centers (ARTCCs) to participate in a collaborative redesign effort, the High Altitude Test (HAT). The SALT tasked the group with creating a demonstration airspace that would blend new tools and technologies, enhance system efficiency, and increase predictability for users and controllers. The seven facilities selected include Oakland ARTCC (ZOA), Seattle ARTCC (ZSE), Salt Lake ARTCC (ZLC), Chicago ARTCC (ZAU), Denver ARTCC (ZDV), Minneapolis ARTCC (ZMP), and Kansas City ARTCC (ZKC), referred to collectively as the HAT-7).

The HAT is tentatively scheduled to commence in the near future. The test area is defined as the geographical airspace that overlies the seven test facilities at FL 390 and above. Features of the test area include routings that rely on full RNAV and global positioning system (GPS) technologies, the use of a conflict probe, User Request Evaluation Tool (URET), reduced vertical separation minima (RVSM), and a navigation reference system (NRS). Charting of the HAT airspace will include Special Use Airspace(s) (SUAs), which are not traditionally depicted on high altitude charts and RNAV points that will be used to facilitate this test. The test airspace was restricted to appropriately equipped aircraft (RNAV and RVSM capable).

The HAT-7 facility design teams collectively developed airspace designed to enhance the NAS and improve system efficiency. Wherever possible, the design allows for non-restrictive routing (NRR), which is defined as airspace where users can plan and fly user-preferred routing. Where structured routing is required, the teams designed both RNAV and parallel RNAV routes (8 miles apart) and used other methods and procedures of making the airspace more efficient.

In an effort to fully understand the issues associated with controllers operating in this type of exclusionary airspace, the SALT decided to conduct some proof of concept (POC) work prior to the HAT. The POC, termed the High Altitude Demonstration (HAD), included both human-in-the-loop (HITL) simulation and some fast-time modeling. The HITL simulation focused primarily on identifying and understanding the impacts of these new procedures on en route controllers. Some preliminary data that could help in subsequent assessments of the benefits and impacts of this exclusionary airspace on users were also collected during this simulation. It is expected that follow-on simulations (both HITL and fast-time) will be needed to fully understand the benefits and impacts for both controllers and users, based on the results of this initial demonstration.

1.3 Study Objectives

The primary objectives for this initial POC HITL demonstration were to:

- Examine the impact of non-restrictive routing on the en route controller.
- Identify the impact of a NRS on the en route controller in airspace with parallel RNAV routes and scenarios that included severe weather and active SUA.
- Identify the impact and Air Traffic Control (ATC) procedural implications associated with the use of tactical RVSM where pilots are flying user-preferred routes.
- Examine the impact of the use of RNAV procedures on the en route controller in airspace where pilots are flying user-preferred routes.
- Gain an understanding of the operational impacts associated with the use of a conflict probe (URET) in this exclusionary airspace.
- Identify the relationships among user-preferred routing, RNAV procedures, tactical RVSM, the NRS, and their impact on system efficiency, capacity, and controller workload.

1.4 Limitations

Due to lack of resources and time constraints, this study was designed as an exploratory effort rather than a full-scale simulation. In that regard, several independent variables were examined among eight participants over a 6-day period. The purpose of this POC was to identify concerns/issues/procedures, obtain feedback from the participants, and to apply this information into potential further work, including the development of the experimental design for a full-scale multi-ARTCC simulation to be conducted in the future.

1.5 Assumptions

1.5.1 RNAV and GPS Technologies

Aircraft flying in the test airspace utilized the latest navigation technologies that allowed them to fly more direct point-to-point routes without the need for ground-based navigational aides. Eliminating the sole use of ground-based navigation allowed for full use of the available airspace, resulting in more direct routes and, consequently, may provide economic benefits to the users.

1.5.2 Parallel RNAV Routes

Parallel RNAV routes were incorporated in several areas of this test airspace to allow for a greater volume of aircraft to fly through airspace constricted by SUAs and through airspace that have a limited number of jet routes available due to lack of ground based NAVAIDs.

1.5.3 URET

Traditional routings funnel aircraft into streams or over points to control where aircraft go and manage the number of confliction points for which each controller is responsible. With the use of a conflict probe, controllers had a tool to strategically plan and control a greater number of random flights without negatively impacting system safety and efficiency.

1.5.4 RVSM

RVSM is a key tool in the development of the HAT airspace. It was used tactically from FL 350 through FL 410 to resolve conflictions. Currently, altitude changes require either 2000 ft or 4000 ft of climb or descent. Through the use of tactical RVSM, altitude changes only required 1000 ft. For the purposes of our simulation, a "†" symbol was added to the data block to indicate to the participants that the aircraft was not properly equipped for RVSM operations. Note: the Air Traffic Display System Replacement Evolution Team (ATDET) has since finalized the design for this indicator which consists of a coral box around the fourth character in the second line of the data block. In addition, the conflict alerting logic was modified to recognize this equipage distinction and, therefore, was not activated unless two RVSM-equipped aircraft were less than 1000 ft apart and had the ability to distinguish RVSM and Non-RVSM aircraft.

1.5.5 Navigational Reference System

A Navigational Reference System (NRS) was developed for this test airspace to allow for the inclusion of structured routing when weather or other factors dictated such as SUA activation/deactivation. The NRS gives both the controller and the pilot an underlying common frame of reference. It allows for greater flexibility to fully utilize available airspace and should provide a better method of communication than our current method of using latitude/longitude coordinates.

2. METHOD

A research team comprised of one Research Psychologist from the NAS Simulation and Analysis Group (ACB-330) and two CPC Subject Matter Experts (SMEs) from the Dallas/Fort Worth ARTCC conducted the simulation.

A team of trained simulation pilots operated aircraft using simple keyboard commands and communicated with the controllers using ATC phraseology. Support engineers from the Real and Virtual Environment Division (ACB-860) and the System Engineering Division (ACB-230) ensured that the simulation system functioned accurately and recorded the required performance data properly.

This POC study was designed as a real-time, high fidelity, HITL, en route simulation. The simulated airspace was based on two adjacent sectors in Memphis ARTCC (ZME) slightly modified for simulation purposes. The SMEs created traffic scenarios that were realistic and provided a level of demand and degree of complexity that engaged both the Radar- (R) and Data- (D) side controllers.

2.1 Participants

Eight Certified Professional Controllers (CPCs) from various ARTCCs participated in this study. Each worked R- and D-side positions for each of the simulation runs. Participants had an average of 16 years of ARTCC experience. Indianapolis ARTCC (ZID) controllers occupied the D-side positions in which URET was available. The URET participants were not subjects for study or evaluation. Participants filled out an Informed Consent form explaining that their participation in this study was strictly voluntary and that their privacy was protected (Appendix A). They also filled out the Background Information Form and Instructions (Appendix B). Strict adherence to all federal, union, and ethical guidelines were maintained throughout the study. Participants were allowed to withdraw from the study at any time without penalty. The simulation evaluated aspects of the high altitude concept and not individual controller performance. Familiarization runs were provided to allow participants to familiarize themselves with the equipment, airspace, and the new procedures that were to be examined. These are described in the following sections.

2.2 Equipment

The simulation test bed was a combination of the En Route Integration and Interoperability Facility (EI^{2}F), the Target Generation Facility (TGF), and the Research Development & Human Factors Laboratory (RDHFL). For a diagram of the laboratory configuration, see Figure 1.

2.2.1 En route Integration and Interoperability Facility

The EI^{2}F included dedicated host emulators, a host interface device (HID)/NAS local area network (LAN), display system replacement (DSR) consoles (both live and simulated), a mini-DSR system support control (DSSC) complex, an FAA interfacility and radar simulator (FIRS), and a mini-TGF.

The test bed included full DSR workstations with all functions normally expected in an operational setting. For the purposes of our study, the EI^{2}F was divided into two sections, one side had URET functionality and the other had strip bays. The D-side used a 20in flat panel display mounted on a moveable arm to make it accessible from both the R-side and D-side positions. This D-side flat panel was used for both URET and the computer readout display (CRD) for the non-URET side of the EI^{2}F. A single D-side keyboard was used for both URET and CRD operations.

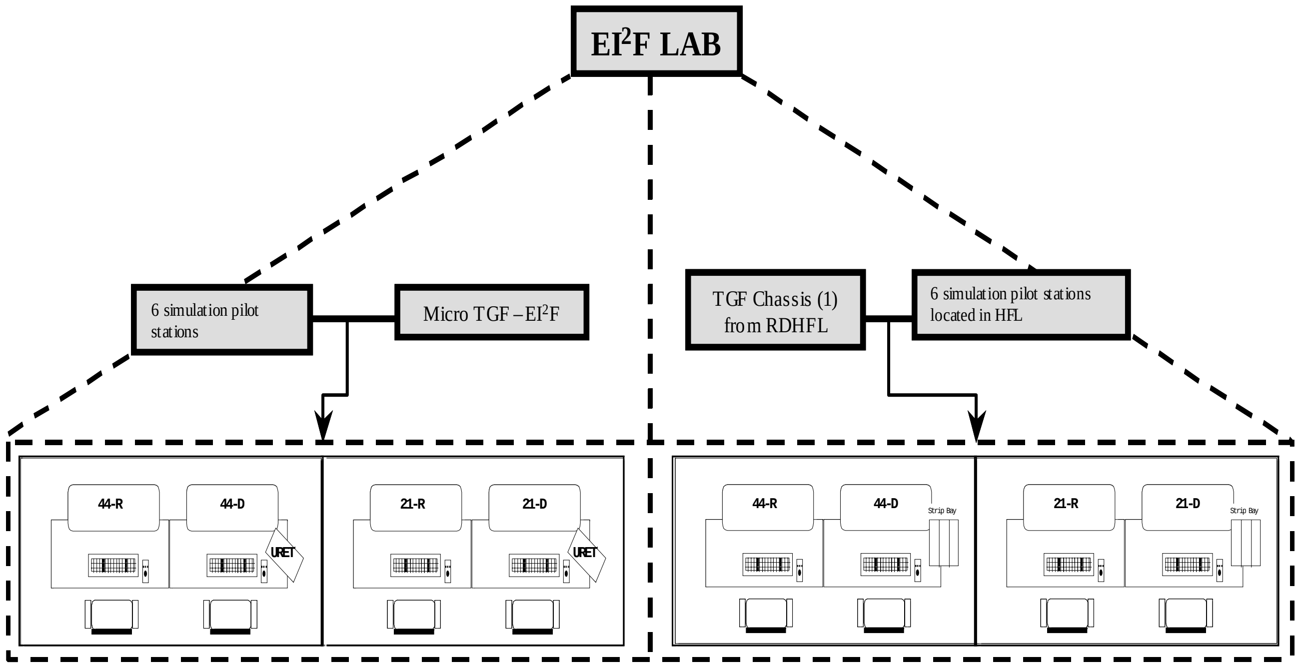

Figure 1. Workstation setup for the EI^2F and the RDHFL.

2.2.2 Target Generation Facility

The TGF generated digital radar messages for targets in our simulated airspace environment. The messages were adapted to mimic actual NAS characteristics by including the radar and environmental characteristics of ZME. Simulated primary and beacon radar data were generated for each target and processed by the Multiple Radar Processing function of the NAS in a manner similar to normal radar data. Flight data blocks contained the same data as currently available at ZME. Target positions were automatically updated at the same rate that was experienced in the ARTCC. To simulate actual aircraft operations, the radar targets maneuvered based on route segments from a flight plan and by the actions of the simulation.

2.2.3 Audio and Video Recording System

An audio and video system was used to collect ATC data during each simulation run. A black and white, low-light micro camera individually captured overall views of each sector. Another low-light, micro-camera captured controller interactions within the sector and their interaction with the displays. Audio signals were recorded from each controller and, along with the video feed, were routed to a central viewing area, which offered an opportunity for members of the SALT to view the simulation without interfering with the simulation process.

2.2.4 Workload Assessment Keypad

A Workload Assessment Keypad (WAK) was provided to R- and D-side controllers separately, with the exception of the D side positions working with URET. The WAK allowed for entering a workload rating at regular intervals electronically. The WAK was programmed to beep at 5-minute intervals. At the time of a beep, the WAK buttons illuminated for 20 seconds. The participant controllers then entered their combined cognitive and physical workload rating at that time. The WAK consisted of a 10-point rating scale where a rating of 1 was very low and rating of 10 was very high. If a workload rating was not given within the 20-second time frame, a default value of 10 was automatically recorded. Six WAKS were linked to a laptop where the workload data were recorded.

2.3 Experimental Design

2.3.1 Airspace

ZME sectors 21 (Conway) and 44 (Pine Bluff) were combined with sectors 20 and 47, respectively. ZME sectors 20 and 47 are both ultra-high altitude sectors (FL 350 and above). See Figure 2 for a depiction of the airspace to be used.

2.3.2 Scenarios

The scenarios were developed from flight plans gathered from a previous simulation conducted in the EI²F using ZME airspace. The data allowed for the realistic representation of sector boundaries, jet routes, and fixes for the chosen and adjacent sectors. To suit simulation needs, the traffic sample was modified. Realistic density and complexity for the sectors were maintained. ATC subject matter experts assisted in developing and validating the scenarios. The order of scenario presentation was randomized to minimize the possible bias effects of order and learning. The scenarios are characterized in Table 1. The simulation schedule and scenario order are depicted in Table 2. Six distinct scenarios were studied relative to a baseline, and each was performed with and without URET, resulting in a total of twenty-four 70-minute simulation runs.

2.3.2.1 Scenario Types

Non-Restrictive Routing

- Two scenarios: (Baseline and NRR)
- Baseline: today’s operations; all aircraft on jet routes/ airways (/A/E/F/G/R -indicator contained in the data block that identifies the onboard navigational equipment to the CPC. Of the five types, /A has the lowest level of navigational equipment.
- NRR: FL 350 and above all properly equipped aircraft (/E/F/G/R) flying direct routes

RVSM

- Two scenarios: (Baseline and RVSM)
- Baseline: Properly equipped aircraft FL 350 and above flying direct routes
- RVSM: Same as baseline with the exception that participants can also use RVSM tactically (for conflict resolution, crossing traffic, etc.) at and above FL350
- Miles in Trail (MIT) restrictions (15 Dallas Fort Worth International Airport (DFW); 10 to New York Center (ZNY) area)

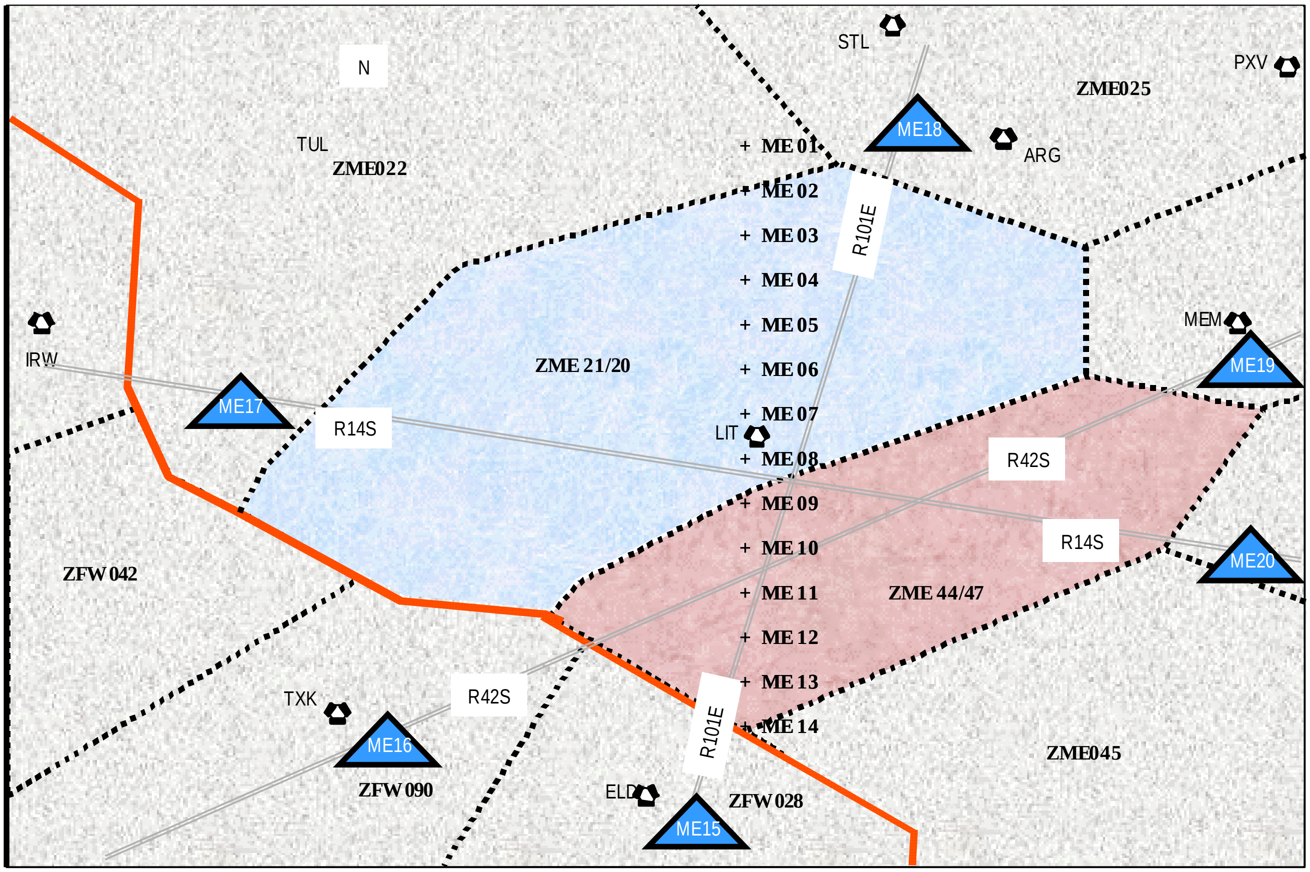

Figure 2. ZME Sectors 21/20 and 44/47 with Parallel RNAV routes and the NRS.

Table 1. Scenario Description

Scenario Description	Non URET	URET
Non-Restrictive Routing (NRR)	Baseline and NRR	Baseline and NRR
Tactical RVSM	NRR and NRR w/Tactical RVSM	NRR and NRR w/Tactical RVSM
Parallel RNAV	NRR and NRR w/RNAV	NRR and NRR w/ RNAV
Weather Grid Navigation	Baseline Weather and Weather w/NRS	Baseline Weather and Weather w/NRS
SUA Grid Navigation	Baseline SUA and SUA w/NRS	Baseline SUA and SUA w/NRS
Mixed	NRR and NRR w/mixed equipage	NRR and NRR w/mixed equipage

Table 2. Simulation Schedule and Scenario Order

2 TEAMS OF 4 + 2 URET D-SIDES

	Mon		Tue		Wed		Thu		Fri	
	STRIPS	URET	STRIPS	URET	STRIPS	URET	STRIPS	URET	STRIPS	URET
AM	PARTICIPANT TRAVEL		AIRSPACE TRAINING		DIRECT	BASE	RVSM	NRR (E)	NRR (E)	RNAV
					BASE	DIRECT	NRR (E)	RVSM	RNAV	NRR (E)
PM	PARTICIPANT TRAVEL		AIRSPACE TRAINING		NRR (E)	NRR (B)	RVSM	NRR (E)	NRR (E)	RNAV
					NRR (B)	NRR (E)	NRR (E)	RVSM	RNAV	NRR (E)
AM	WX	WX GRID	SUA	SUA GRID	MIXED	NRR (E)	DEBRIEFING		PARTICIPANT TRAVEL	
	WX GRID	WX	SUA GRID	SUA	NRR (E)	MIXED				
PM	WX	WX GRID	SUA	SUA GRID	MIXED	NRR (E)	DEBRIEFING		PARTICIPANT TRAVEL	
	WX GRID	WX	SUA GRID	SUA	NRR (E)	MIXED				

Note: A typical scenario will consist of 5-minute ramp-up time, followed by 65 minutes of traffic.

RNAV

- Two scenarios: (Baseline and RNAV)
- Baseline: Properly equipped aircraft FL 350 and above flying direct routes
- RNAV: Same as baseline with the exception that participants can also put properly equipped aircraft on parallel RNAV routes
- MIT restrictions (15 DFW; 10 to ZNY area)

Navigational Reference System (Weather Scenario)

- Two scenarios: (Baseline and Weather NRS)
- Baseline: Properly equipped aircraft FL 350 and above flying direct routes with severe weather. Participants have to route traffic around weather system using vectors.
- Weather NRS: Same as baseline, with the exception that FL 350 and above participants can use the NRS to route multiple paths of traffic around weather.

Navigational Reference System (SUA Scenario)

- Two scenarios: (Baseline and SUA NRS)
- Baseline: Properly equipped aircraft FL 350 and above flying direct routes. Once SUA goes active, participants have to route traffic around SUA using vectors
- SUA NRS: Same as baseline, participants can use the NRS to re-route traffic. Pilots also begin to file flight plans around SUA

Mixed Environment

- Two scenarios (Baseline and Mixed)
- Baseline: Properly equipped aircraft FL 350 and above flying direct routes
- Mixed: Properly equipped aircraft FL 350 and above flying direct routes. Minimally equipped (/A) aircraft were allowed into exclusionary airspace (FL 350 and above) All tools available (RVSM, RNAV, NRS)

The same data were recorded, collected, and analyzed for each of the previous cases, including the baseline(s). This approach allowed the impact of each capability to be assessed and measured relative to the respective baseline for each condition. To ensure that valid comparisons could be made, the conditions being simulated (e.g., traffic level, equipment) were held constant in each of the six distinct cases.

2.3.2.2 Scenario Conditions

The scenarios were based on 2001 traffic levels and represented realistically busy traffic periods. Scripted events that were added to specific scenarios include:

- Weather
- Pilot altitude requests
- Transitioning aircraft (both RVSM and non-RVSM-approved)
- SUA activation/deactivation
- Dependent Variables

The laboratory automated data collection system produced a large set of common performance measures that were typically examined in ATC simulation research (Buckley, DeBaryshe, Hitchner, & Kohn, 1983). Table 3 lists a set of objective performance measures collected by the system separated into three categories: safety, capacity, and efficiency.

Additionally, controller workload was sampled in real time during each scenario using the WAK method. Upon completion of each scenario, Post-Scenario Questionnaires were administered. See Appendix C.

Table 3. ATC Performance Measures

1-Safety	• NECNF (ER) – Number of standard en route conflicts • NBSCNF – Number of between sector conflicts
2-Capacity	• NCOMP – Number of flights completed
3-Efficiency	• NPTT – Number of A/G communications • DPTT – Average duration of each A/G communication • NALT – Frequency of altitude clearances • NHDG – Frequency of heading clearances • NSPD – Frequency of airspeed clearances • DIST – Distance flown for all flights

2.4 Orientation Sessions

Representatives from the simulation team briefed the participants in a classroom setting prior to entering the laboratory area. The participants were encouraged to ask questions. We provided them with all appropriate briefing materials. The briefing covered the following topics:

- Human Research Minimal Risk Consent Document
- Participants role in the study
- Study objectives
- Study methodology
- Laboratory equipment and configuration
- Rules and procedures

Following the briefing, the participants were requested to complete the Participant Consent Document contained in Appendix A and the ATC Background Questionnaire contained in Appendix B.

2.4.1 ATC Laboratory Familiarization

Although the DSR laboratory was configured to replicate two ARTCCs (one with URET resources, the other without), there were some differences, specifically in the communications realm. In the field, CPCs use the Voice Switching and Control System (VSCS). VSCS provides CPCs at ARTCCs with air-to-ground (A/G) and ground-to-ground (G/G) voice communication capability. The EI^2F is not equipped for VSCS; however, a communications system was in place and was adequate for the purposes of our study. All differences were briefed in detail, and instructions on how to operate the communications system were provided.

2.4.2 TGF Simulation Pilot/Ghost Sector Controller Training

In the weeks prior to the simulation, Simulation Pilots and Ghost Sector Controllers were rigorously trained to assure operationally consistent, accurate, and timely responses to controller instructions and requests. Lectures on the following topics were performed:

- Study objectives
- Study methodology
- Airspace structure

- Air traffic characteristics
- Aircraft equipage
- Controller procedures

Additionally, the Simulation Pilots and Ghost Sector Controllers performed all scenarios during the shakedown period.

3. RESULTS

For our purposes, we used the *t*-test to determine statistical significance. The *t*-test is the most commonly used method to evaluate the differences in means between two groups even if the sample sizes are very small. The *t*-test compares two averages and checks if the two averages are different due to chance alone. The *t*-test will never give the researcher 100% assurance that the two means actually differ. It is common practice to accept 95% assurance as sufficient guarantee. We intend to use the information collected in this study to shape the experimental design for the large-scale multi-ARTCC simulation to be conducted in the future. As expected, there were very few statistically significant findings due to the large number of variables examined with such a small subject pool. The participants worked both sectors for each of the conditions, therefore, the data were collapsed across both sectors (21 and 44), and we focused on the impact to the system as a whole instead of individual sectors. The results are grouped into three sections for each of the 6 days of simulation.

The sections consist of the objective data collected from the TGF automated data collection system, the subjective workload data obtained from the WAKs, and the subjective ratings gathered from the post-scenario questionnaires. There is a discussion for each section. The results are further broken down into URET and non-URET (flight strips) runs. It is important to clarify that comparisons between URET and flight-strips runs are not possible because none of the eight CPCs who participated in this simulation were trained on URET. The two individuals who worked the URET position were from Indianapolis ARTCC and were not part of the evaluation. The layout of the results section is as follows:

- Day one: Non-Restrictive Routing
- Day two: Tactical RVSM
- Day three: Parallel RNAV routes
- Day four: NRS (weather scenario)
- Day five: NRS (SUA scenario)
- Day six: Mixed Environment

3.1 Loss of Separation

Typically, losses of separation that occur in a novel simulation environment are not very meaningful, especially when participants are working in an unfamiliar airspace and implementing new procedures; however, it is still something we report. The frequencies of losses of separation are depicted in Figure 3. According to the data, participants had more losses of separation in the RVSM and the Mixed Baseline scenarios, both with URET and without URET.

Overall, participants viewed the use of tactical RVSM as very favorable. The TGF output variable aircraft proximity index (API), a 1 to 100 scale of aircraft proximity where 1 is a minor loss of separation and 100 is a mid-air collision) indicated that the few losses of separation that occurred during the RVSM scenarios were minor, with the value(s) not exceeding 6.

Participants had more losses of separation in the Mixed Baseline scenarios than in any other (see Figure 3). These losses were also minor (API not exceeding a 12 on the 100-point scale).

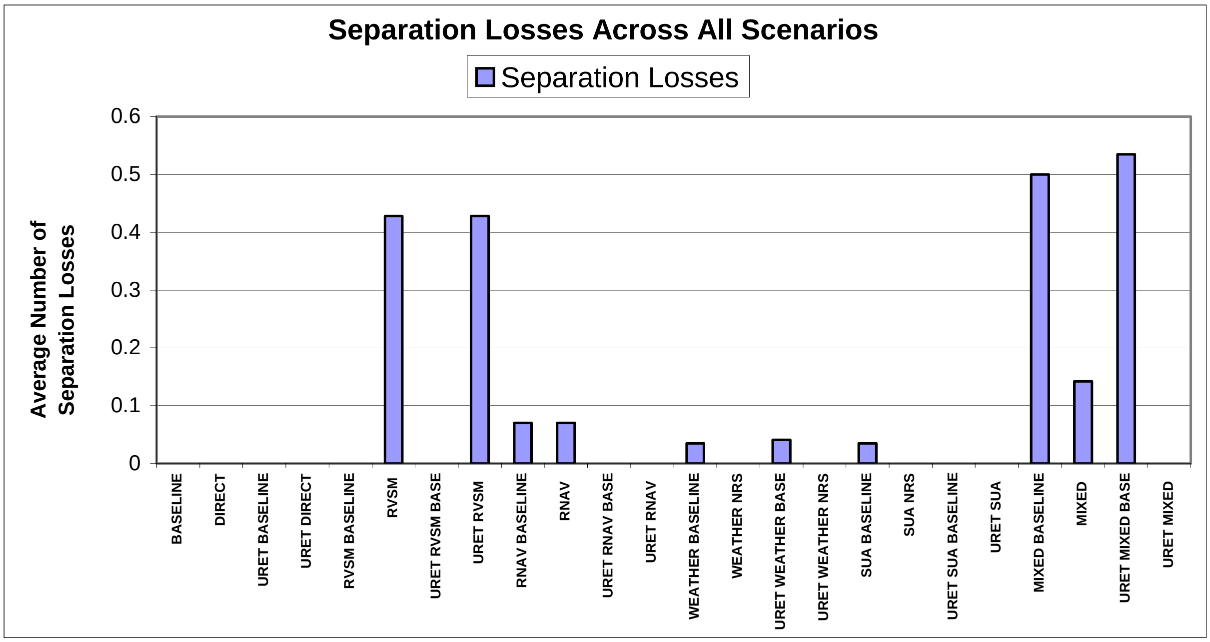

Figure 3. Losses of separation across scenarios.

<u>3.2 Non-Restrictive Routing</u>

<u>3.2.1 TGF Output</u>

From the automated TGF data collection system, we extracted the frequency of altitude, heading and speed changes. The means are depicted in Figure 4.

In addition, we examined the frequency and duration of A/G communications. The means are presented in Figures 5 and 6 respectively. There were no significant differences found among the TGF data for these two scenarios.

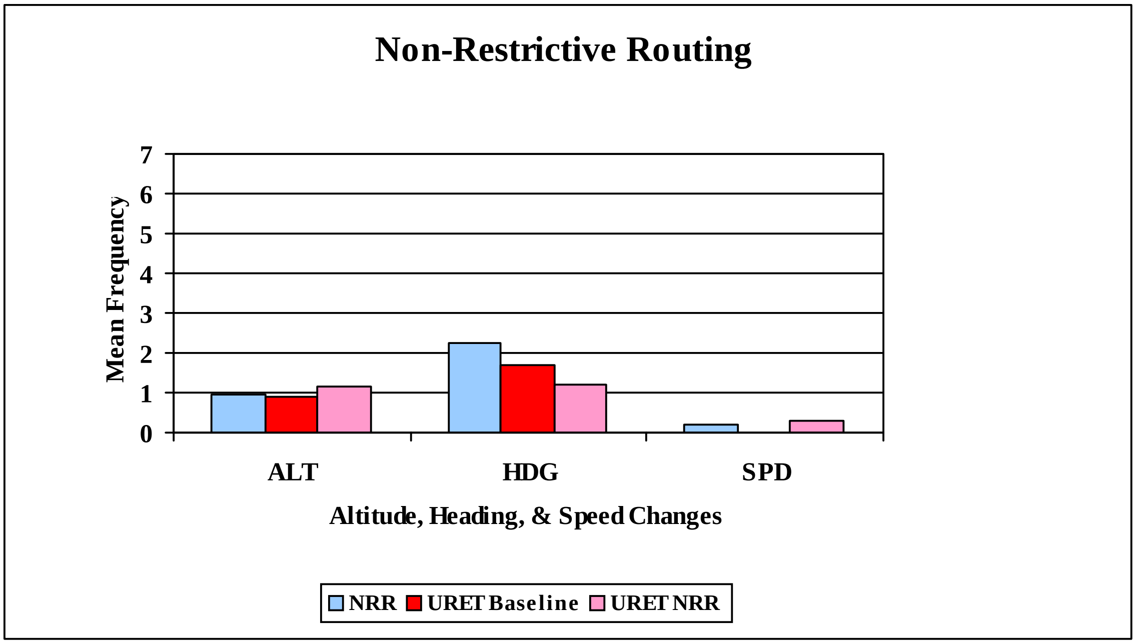

Figure 4. TGF output for the non-restrictive routing scenarios.

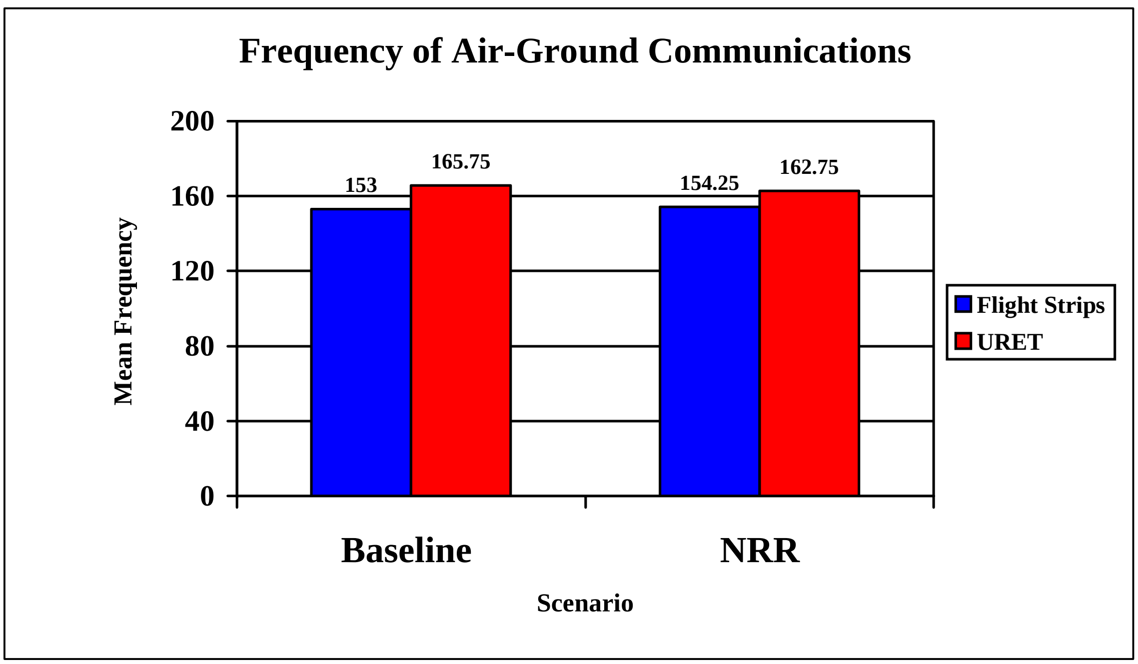

Figure 5. Frequency of A/G communications for the non-restrictive routing scenarios.

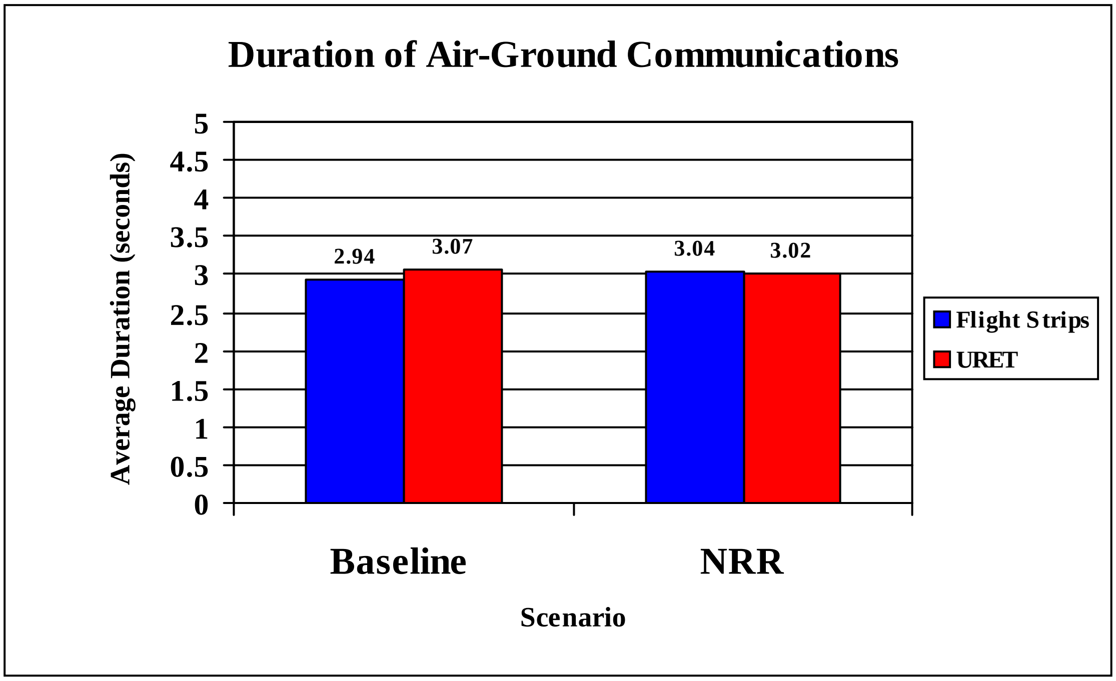

Figure 6. Average duration of each A/G communication for the non-restrictive routing scenarios.

3.2.2 Subjective Workload

The average workload ratings collected via the WAKs are captured in Figure 7. There were no significant differences among these workload scores.

3.2.3 Post-Scenario Questionnaires

The Post-Scenario Questionnaire can be found in Appendix C. We examined only the questions in which a rating was solicited, as some of the questions were open-ended and, therefore, not included in the analysis. The questions can be separated into two categories: workload related questions and scenario difficulty questions. Questions #1, #2, #4, and #5 are workload specific, and #7, #8, and #9 are related to scenario difficulty. The means are depicted in Figure 8.

No significant differences were found; therefore, it is evident that when participants used URET, they rated their workload and the difficulty of the scenario lower than when they worked the same scenario using flight strips.

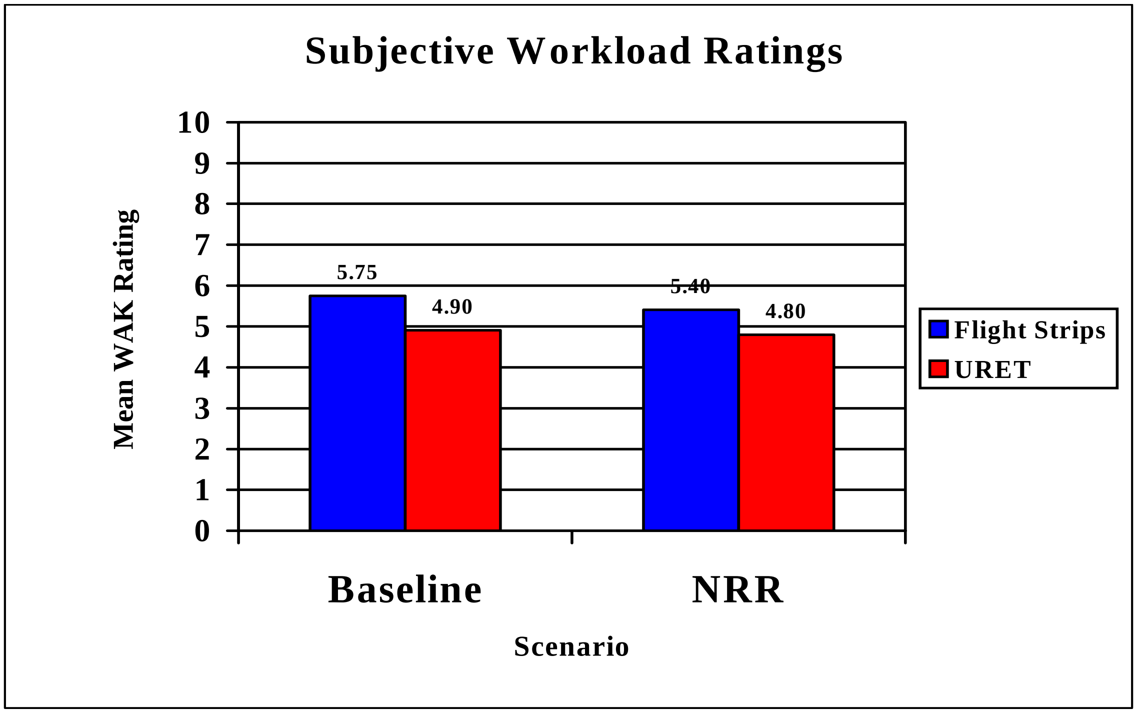

Figure 7. Average workload ratings for the non-restrictive routing scenarios.

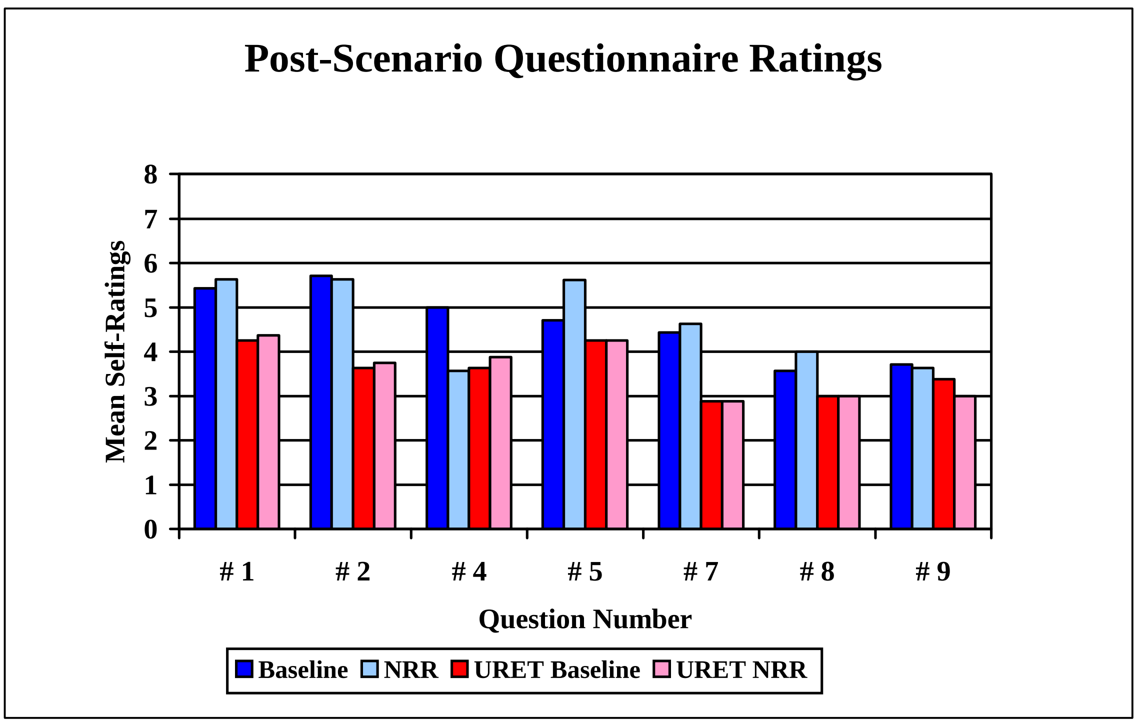

Figure 8. Post-Scenario questionnaire ratings for the NRR scenario.

3.2.4

Discussion

It was anticipated by the research team that the NRR scenario would elicit higher ratings of workload and negatively impact controller efficiency. The rationale was that with aircraft only on existing jet routes (as in the baseline scenario), the conflict points would be restricted to airway intersections as opposed to conflict points being created throughout the sector(s), as in the NRR scenario. Furthermore, handoffs in the baseline condition were accepted and initiated where sector boundaries and airways intersected. This was not the case in the NRR scenario where the handoffs occurred at random points along sector(s) boundaries. Working in an airspace in which the participants were unfamiliar may have had some influence on the direction of the results for this particular type of scenario.

3.3 Tactical RVSM

3.3.1 TGF Output

Frequency of altitude, heading, and speed changes are depicted in Figure 9. When using URET, participants, on average, made significantly more altitude changes when the tactical RVSM capability was available compared to the baseline. Frequency and duration of A/G communications are shown in Figures 10 and 11. There were no significant differences among these variables.

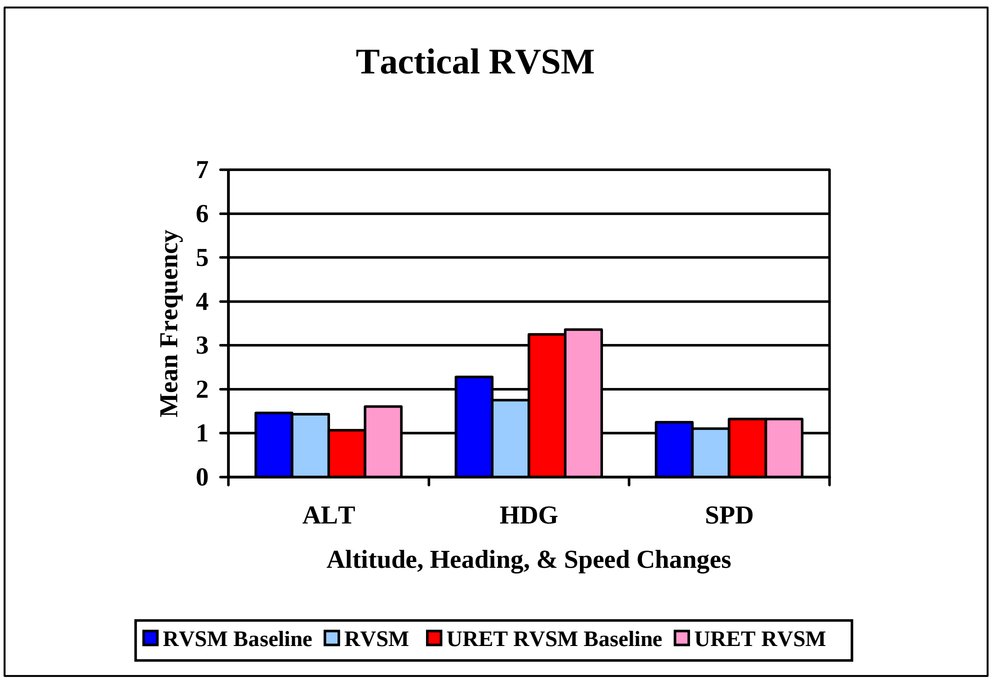

Figure 9. TGF output for the tactical RVSM scenarios.

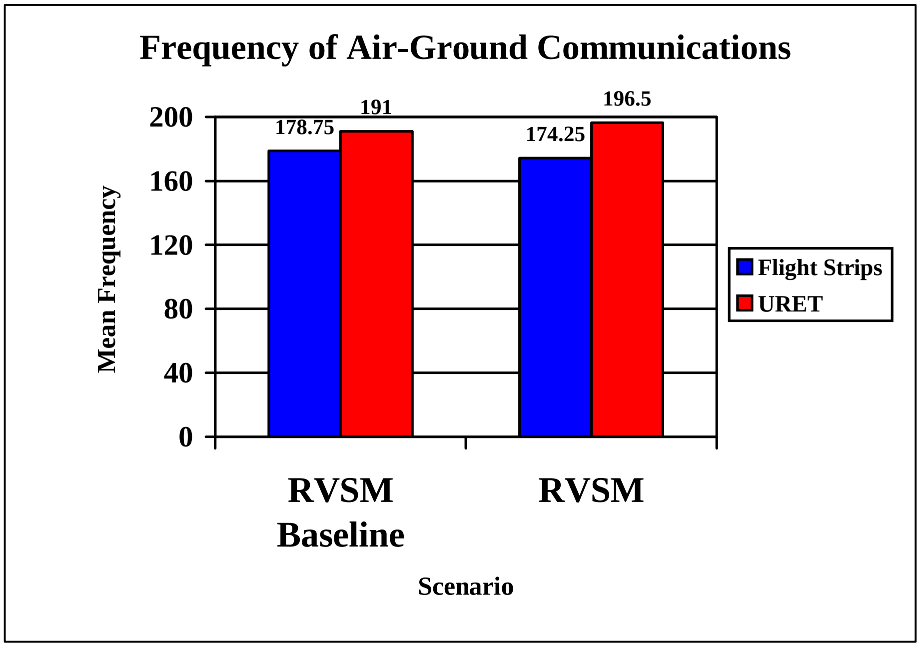

Figure 10. Frequency of A/G communications for the tactical RVSM scenarios.

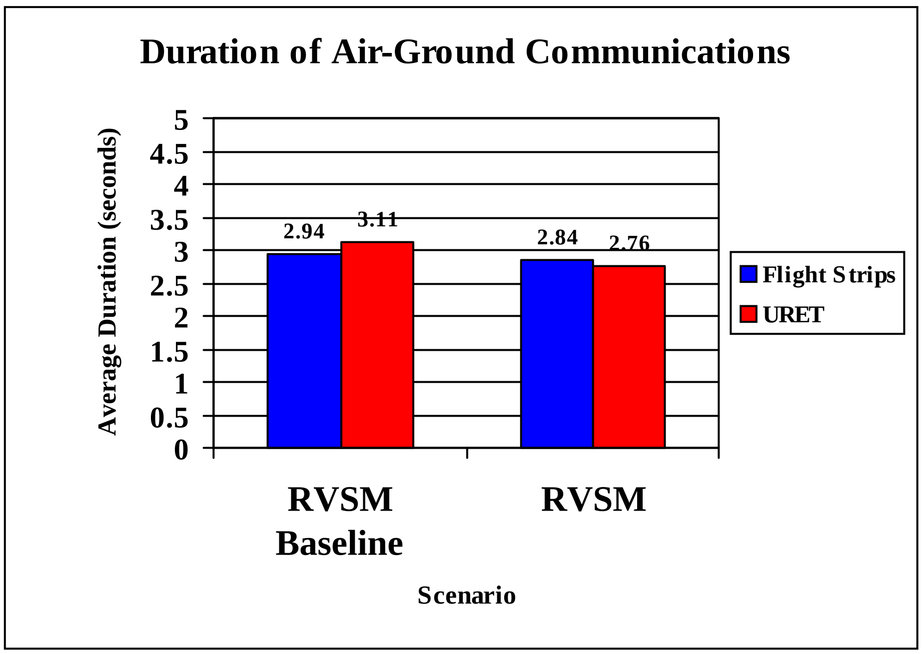

Figure 11. Average duration of each A/G communication for the tactical RVSM scenarios.

3.3.2

Subjective Workload

The average workload ratings for the tactical RVSM scenarios are shown in Figure 12. There were no significant differences; however, there was a trend for lower workload ratings when tactical RVSM was available compared to the baseline.

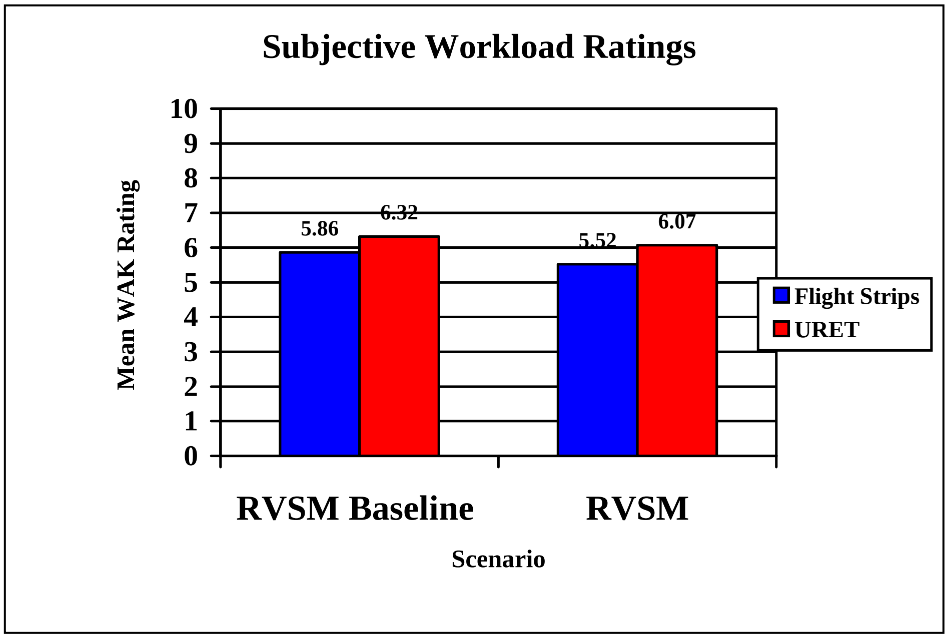

Figure 12. Average workload ratings for the tactical RVSM scenarios.

3.3.3 Post-Scenario Questionnaires

This scenario had MIT restrictions (15 DFW and 10 ZNY), so a question about the impact of the MIT restrictions (item 10) was included in this analysis in addition to the questions on workload (items 1, 2, 4, and 5) and scenario difficulty (items 7, 8, and 9). The means are captured in Figure 13, and, no significant differences were found. Therefore, it was apparent that when participants used URET, they rated their workload and the difficulty of the scenario lower than when they worked the same scenario without URET availability .

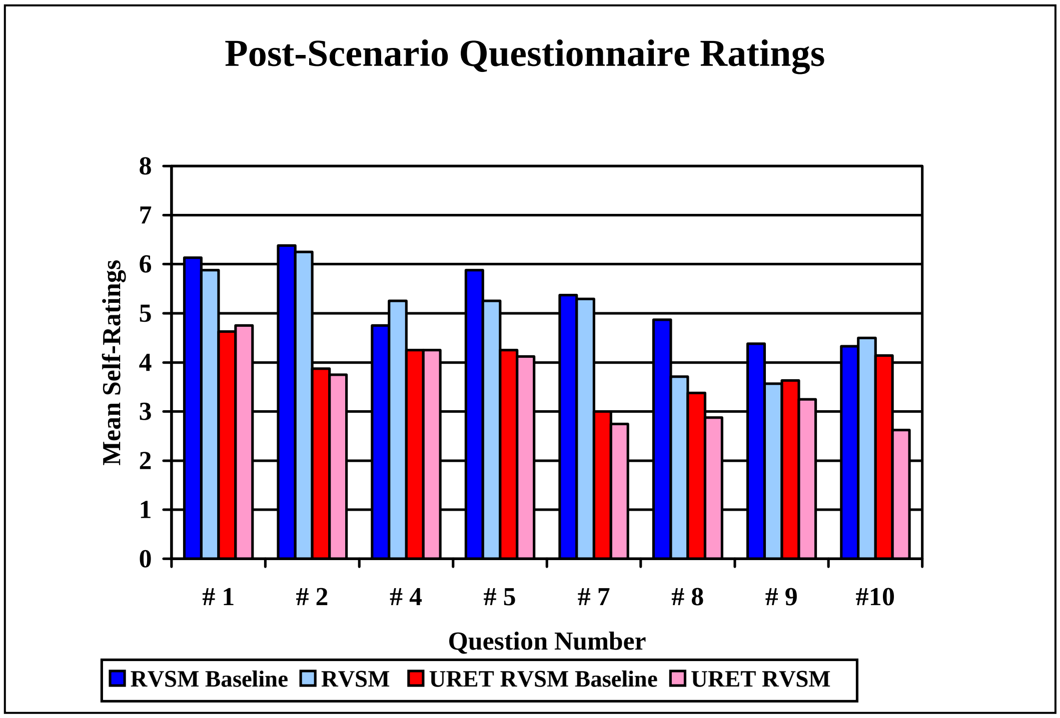

Figure 13. Post scenario questionnaire ratings for the tactical RVSM scenarios.

3.3.4 Discussion

Although there were no significant differences, there appeared to be a trend for decreases in workload and frequency of A/G communications in the tactical RVSM scenarios on the flight strip side. When using a URET D-side, participants had slightly more (although not significantly more) communications during the RVSM scenario relative to the baseline.

3.4 Parallel RNAV Routes

3.4.1 TGF Output

From the automated TGF data collection system, we extracted the frequency of heading, speed, and/or altitude changes. There were no significant differences found among these variables. The means are depicted in Figure 14. The efficiency indicators, frequency and duration of A/G communications, also yielded no significant differences. The means of these two variables are captured in Figures 15 and 16.

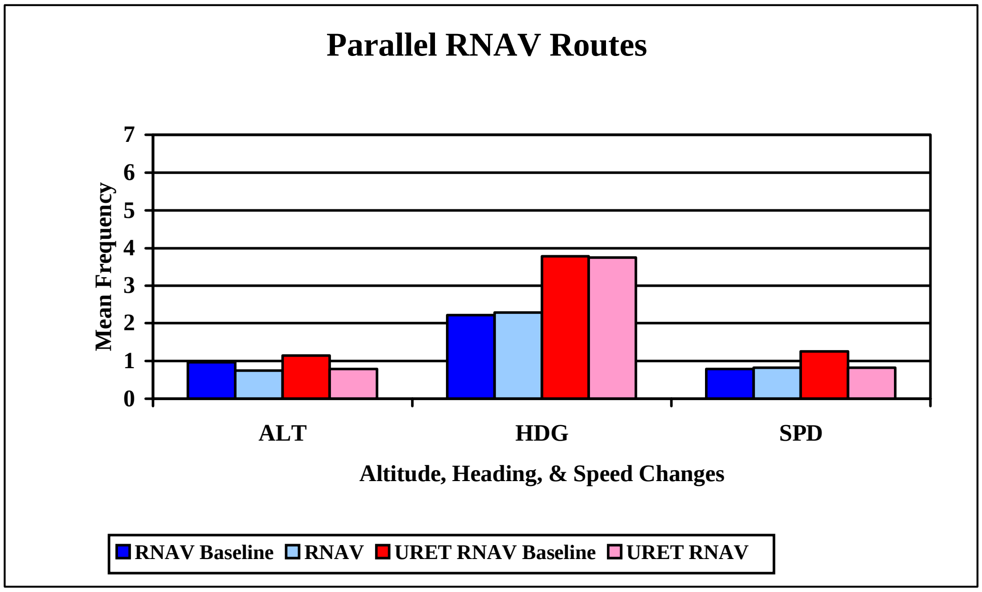

Figure 14. TGF output for the RNAV scenarios.

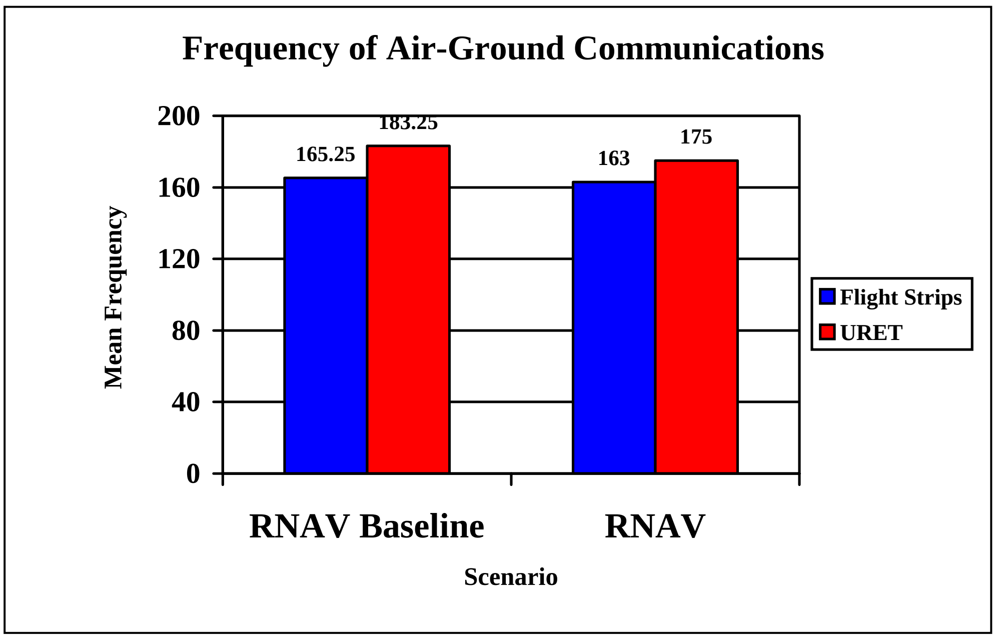

Figure 15. Frequency of A/G communications for the RNAV scenarios.

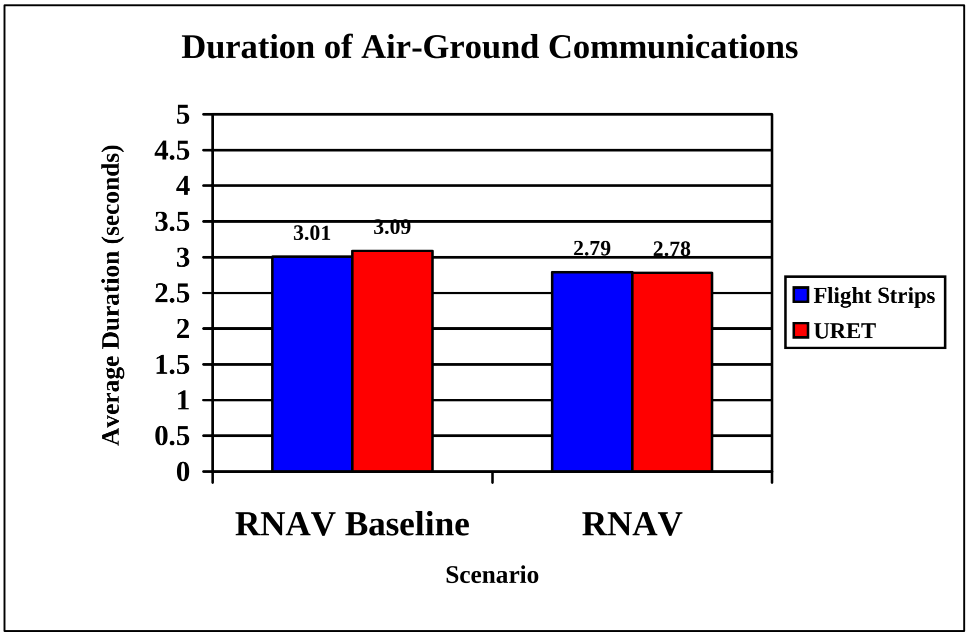

Figure 16. Average duration of each A/G communication for the RNAV scenarios.

3.4.2 Subjective Workload

The average workload ratings for the RNAV scenarios are depicted in Figure 17. On the flight strip side, participants rated their workload significantly higher when RNAV routes were available. Overall, participants felt that RNAV routes were more workload intensive when they were working the strip side of the room as opposed to when they had a URET D-side.

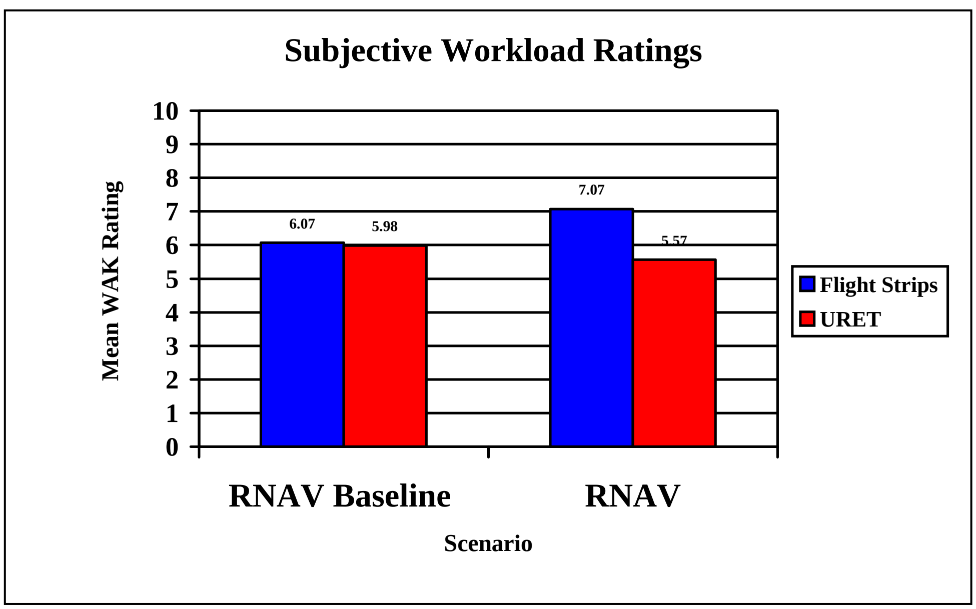

Figure 17. Average workload ratings for the RNAV scenarios.

3.4.3 Post Scenario Questionnaires

This scenario also had MIT restrictions (15 DFW and 10 ZNY), so a question about the impact of the MIT restrictions (item 10) was included in this analysis in addition to the questions on workload (items 1, 2, 4, and 5) and scenario difficulty (items 7, 8 and 9). The mean ratings are captured in Figure 18. On the strip side, participants rated their mental workload (Question #1 e.g., planning and coordinating) significantly lower when RNAV routes were available. This is in contrast to the on-line measures of workload (the WAK), which revealed higher average ratings on the strip side of the lab when RNAV routes were available. There were no other significant differences found.

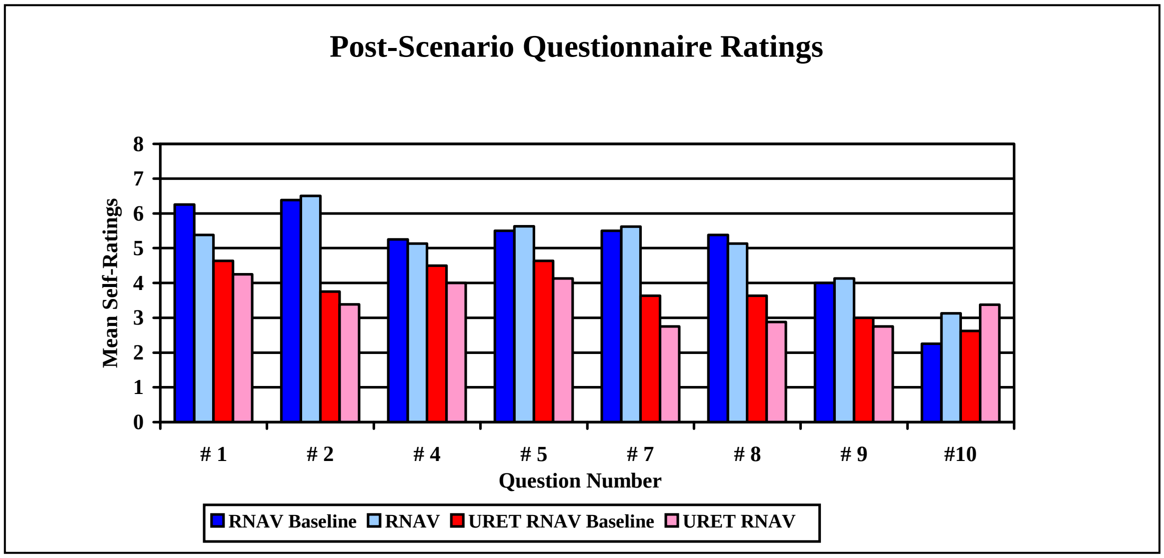

Figure 18. Post-scenario questionnaire ratings for the RNAV scenarios.

3.4.4 Discussion

The results indicate that when participants had a URET D-side, there was a trend for decreased workload and increased controller efficiency. However, when working the same scenario with the traditional D-side using flight strips, there appears to be more of a disassociation of measures. On the one hand, on-line subjective workload ratings significantly increased when parallel RNAV routes were available, but when participants were asked to rate their mental workload in the Post-Scenario Questionnaire, the ratings were significant in the opposite direction. One explanation for this disparity may be related to how the baseline scenario was created. In order to compare the baseline scenario to the RNAV scenario, the research team had to keep traffic flows the same, so any differences in performance or workload could be attributed to the absence or presence of parallel RNAV routes. We had to create situations (e.g., overtakes) that would encourage the use of the RNAV routes during the RNAV scenario, but, at the same time, we did not want to create an unmanageable baseline scenario.

3.5

NRS (Weather Scenario)

3.5.1 TGF Output

From the automated TGF data collection system, we extracted the number of separation losses and frequency of heading, speed, and/or altitude changes. There were no significant differences found among these variables. The means are depicted below in Figure 19. The efficiency indicators, frequency, and duration of A/G communications, also yielded no significant differences. The means of these two variables are captured in Figures 20 and 21.

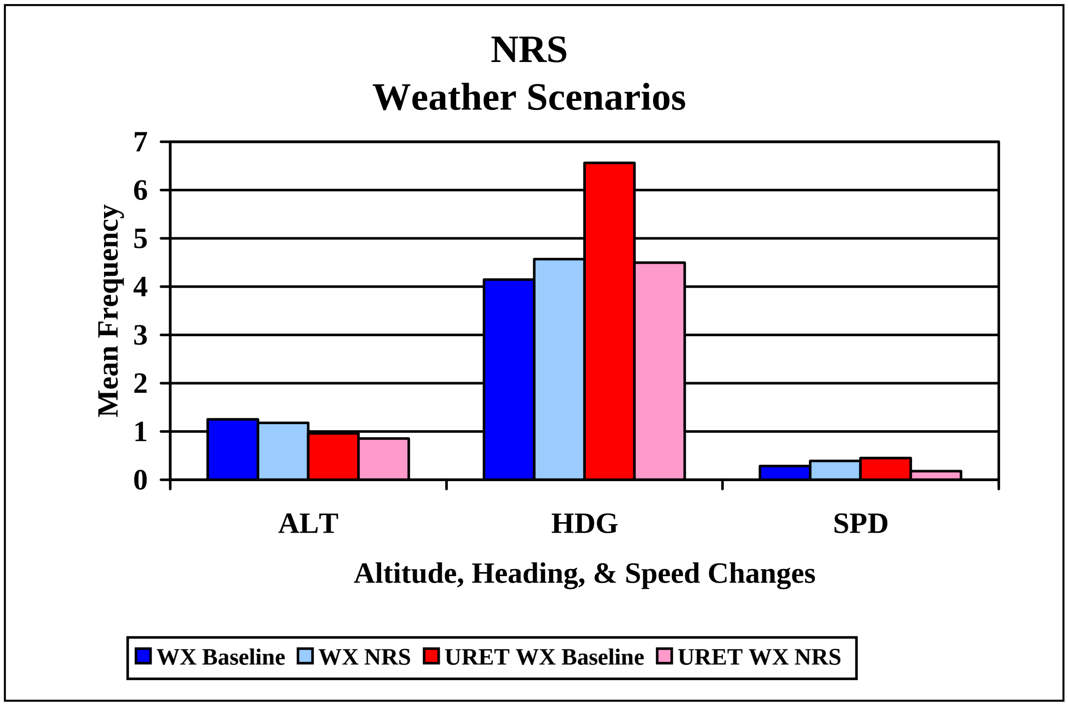

Figure 19. TGF output for the NRS weather scenarios.

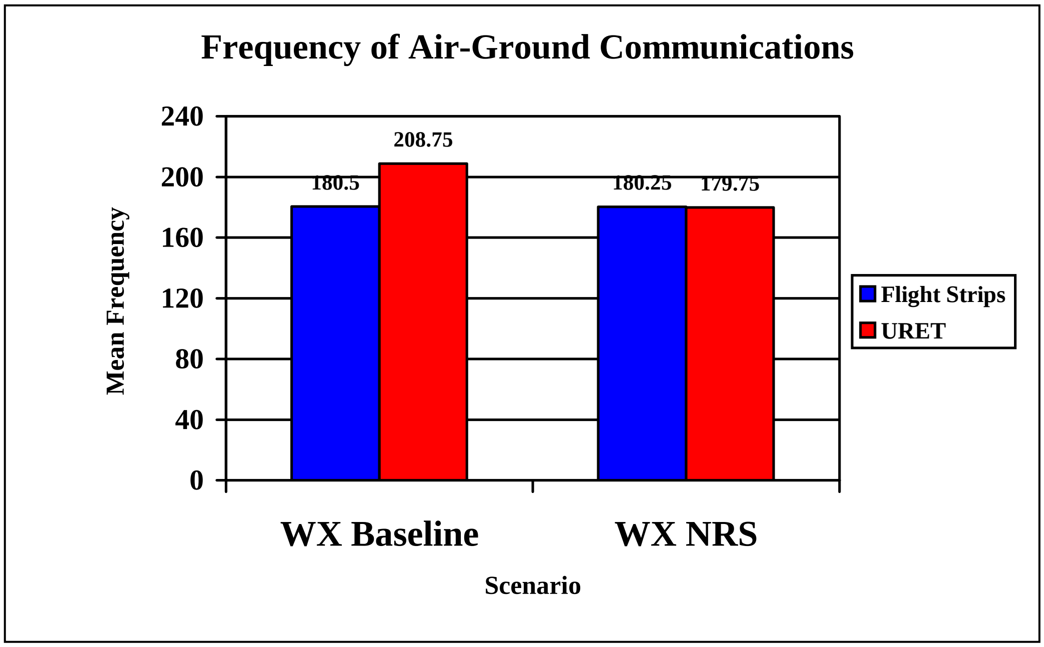

Figure 20. Frequency of A/G communications for the weather scenarios.

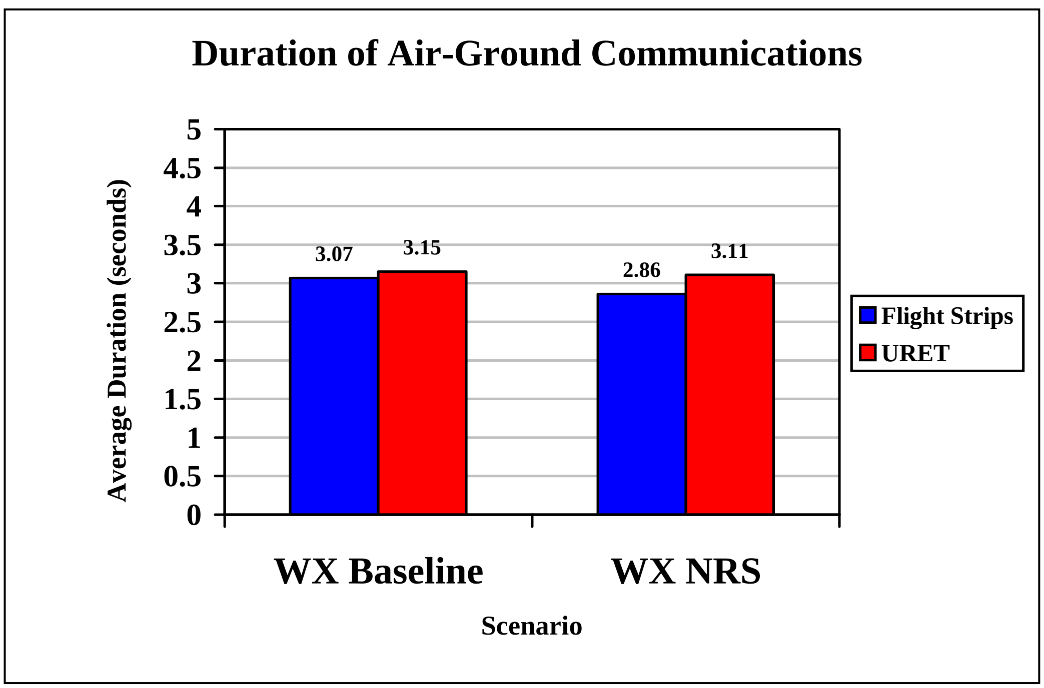

Figure 21. Average duration of each A/G communication for the weather scenarios.

3.5.2

Subjective Workload

Average workload ratings are shown in Figure 22. When working with flight strips, participants rated their workload significantly less when the NRS was available. There were no differences when working with URET.

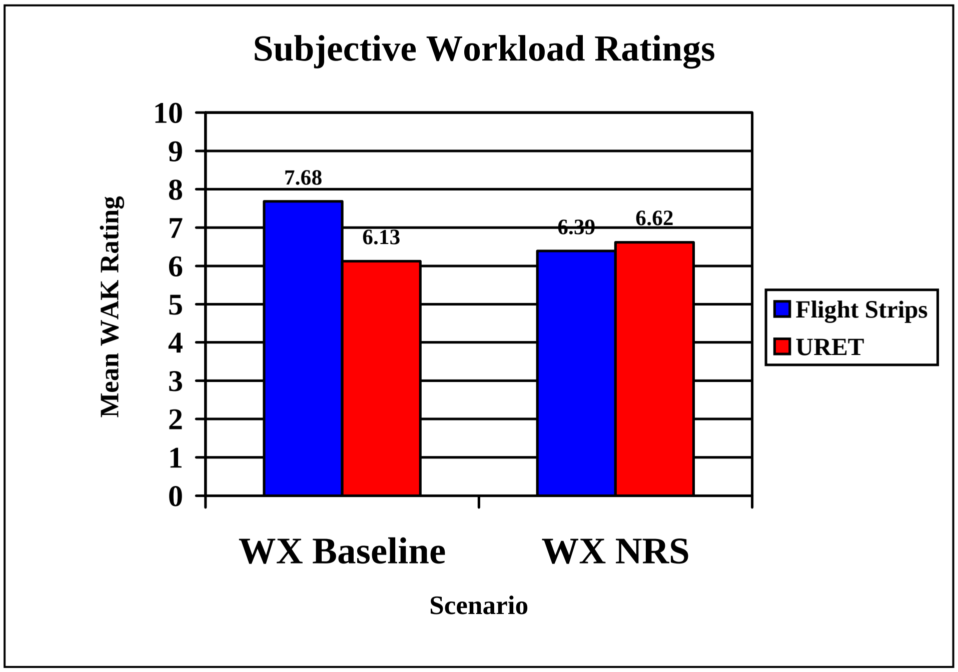

Figure 22. Average workload ratings for the weather scenarios.

3.5.3 Post-Scenario Questionnaires

The mean ratings of the Post-Scenario Questionnaires are shown in Figure 23. For this analysis, a question was added that dealt with issuing lat/long clearances if a weather/SUA was present (item #6). On the strip side, participants rated the difficulty resolving conflicts (item # 8) significantly less when using the NRS for weather deviations as opposed to using lat/longs to re-route traffic around the weather system.

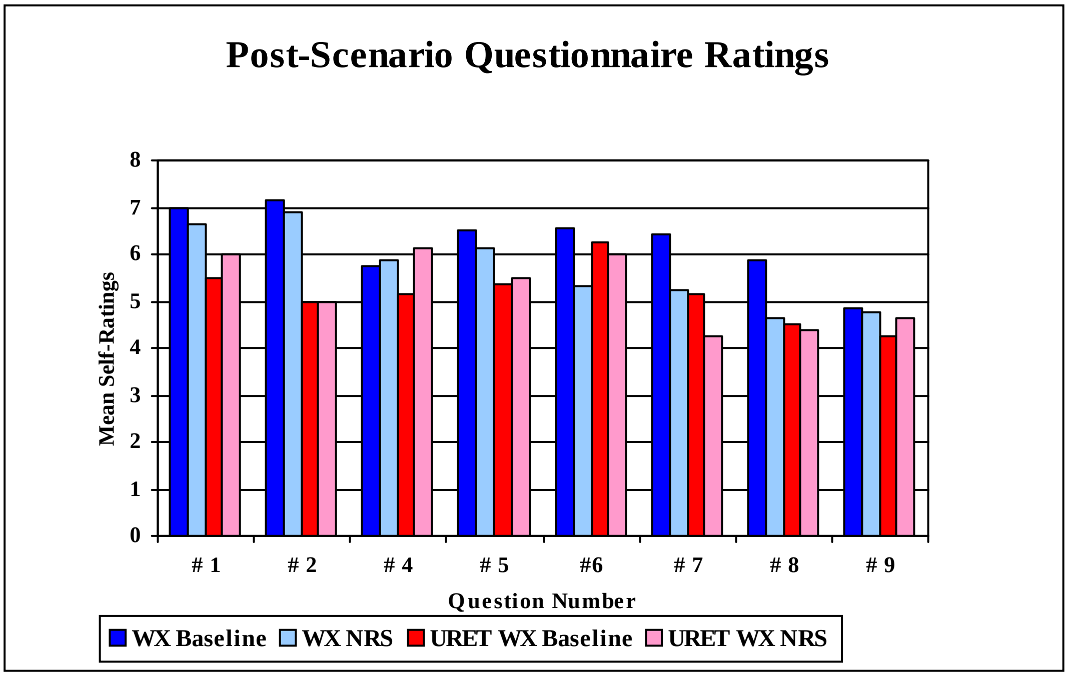

Figure 23. Post-scenario questionnaire ratings for the weather scenarios.

3.5.4 Discussion

As expected, the availability of the NRS resulted in significantly lower workload scores for participants when using a flight strip D-side. Participants also felt it was easier to resolve conflicts when the NRS was available. When working these scenarios with URET, the availability of the NRS had no impact on performance or workload.

3.6 NRS (SUA Scenario)

3.6.1 TGF Output

From the automated TGF data collection system, we extracted the frequency of heading, speed, and/or altitude changes. There were no significant differences found among these variables. The means are depicted in Figure 24. The efficiency indicators, frequency and duration of A/G communications, yielded significant differences on the strip side. In other words, when working on the flight strip side of the lab, participants had fewer A/G communications, and the duration of those communications was significantly shorter when using the NRS to reroute traffic around the active SUA. The means of these two variables are captured in Figures 25 and 26.

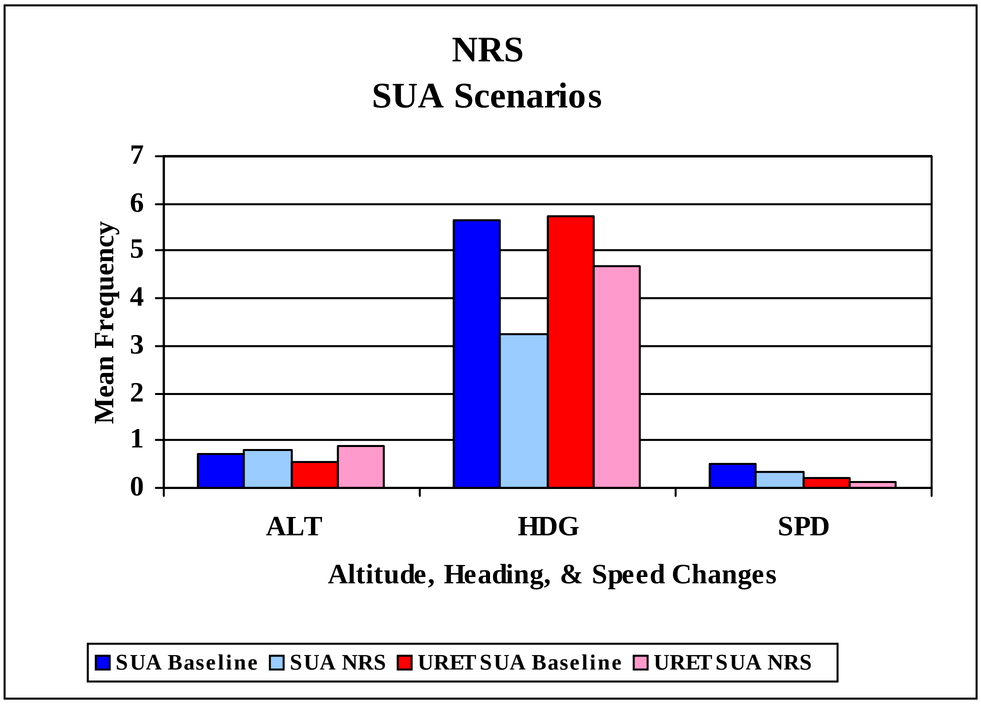

Figure 24. TGF output for the NRS SUA scenarios.

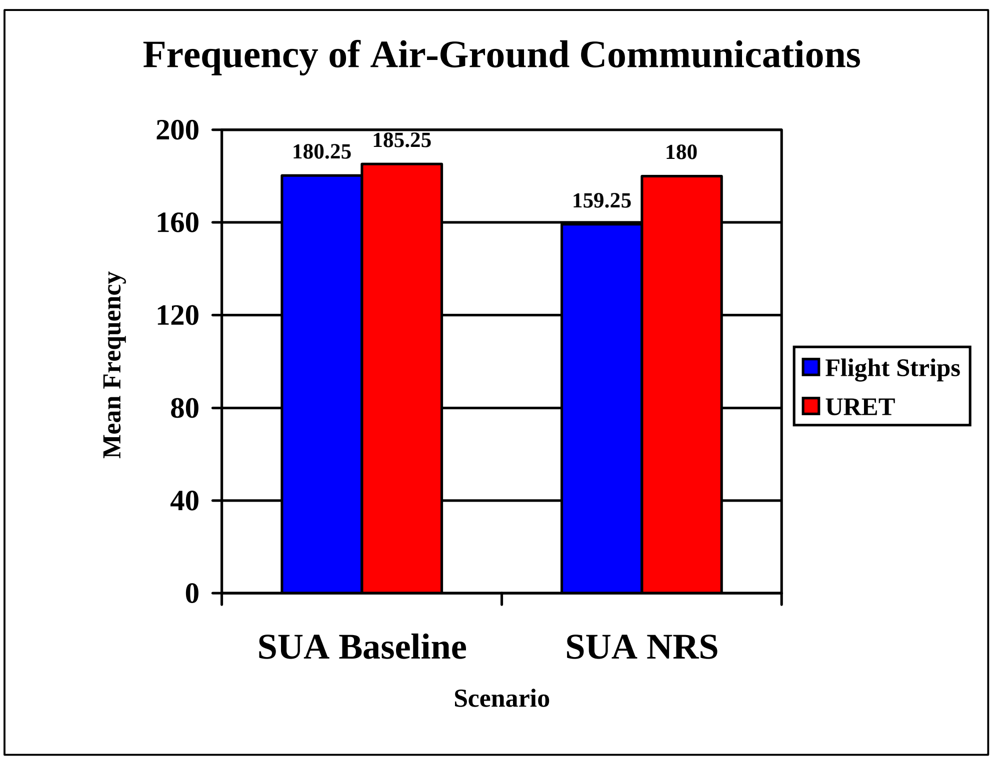

Figure 25. Frequency of A/G communications for the SUA scenarios.

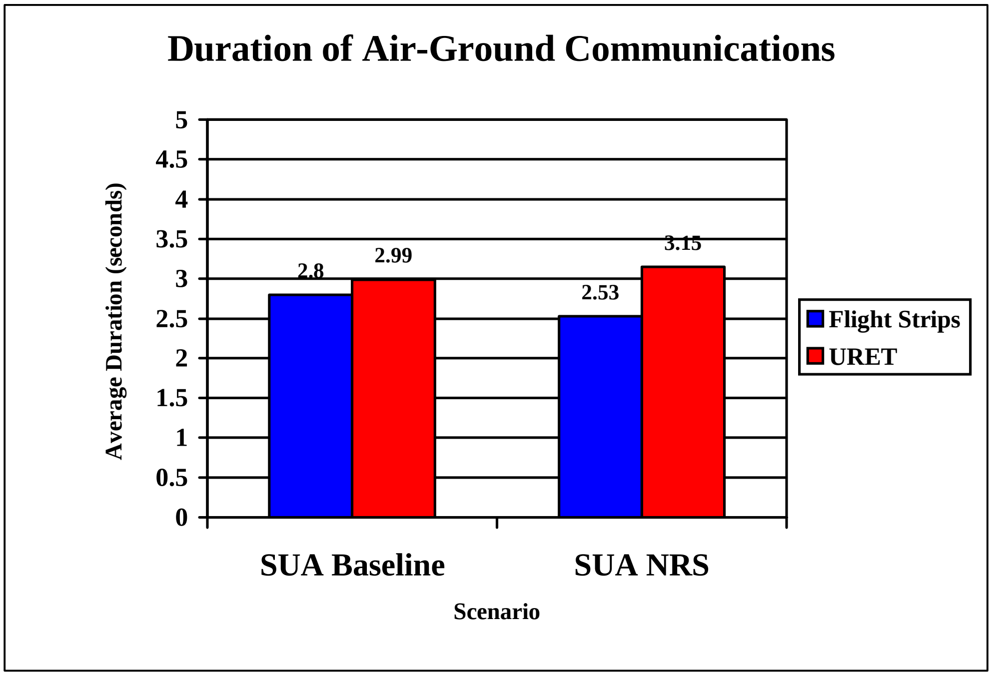

Figure 26. Average duration of each A/G communication for the SUA scenarios.

3.6.2 Subjective Workload

The average workload ratings are depicted in Figure 27. There were no significant differences found between the two scenarios.

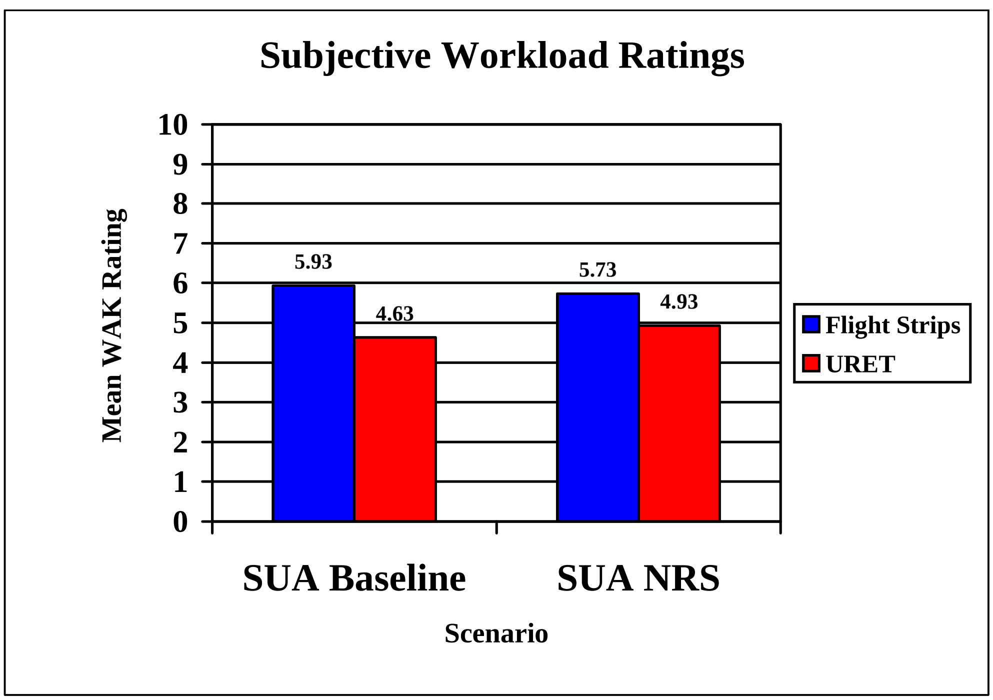

Figure 27. Average workload ratings for the SUA scenarios.

3.6.3 Post-Scenario Questionnaires

The mean ratings from the Post-Scenario Questionnaires are shown in Figure 28. For this analysis, a question was added that dealt with issuing lat/long clearances if a weather/SUA was present (item #6). On the strip side, several significant differences were found. For item 5, participants rated their experience with "controlling aircraft FL 350 and above" as significantly more workload intensive in the baseline condition than when the NRS was available. In addition, participants had a more difficult time both detecting conflicts (item #7) and resolving conflicts (item #8) in the baseline condition than when the NRS was available. For the URET side, participants had more difficulty "accepting, and/or handing off aircraft at random points on (their) sector boundaries" (item #9) in the baseline condition than when the NRS was available.

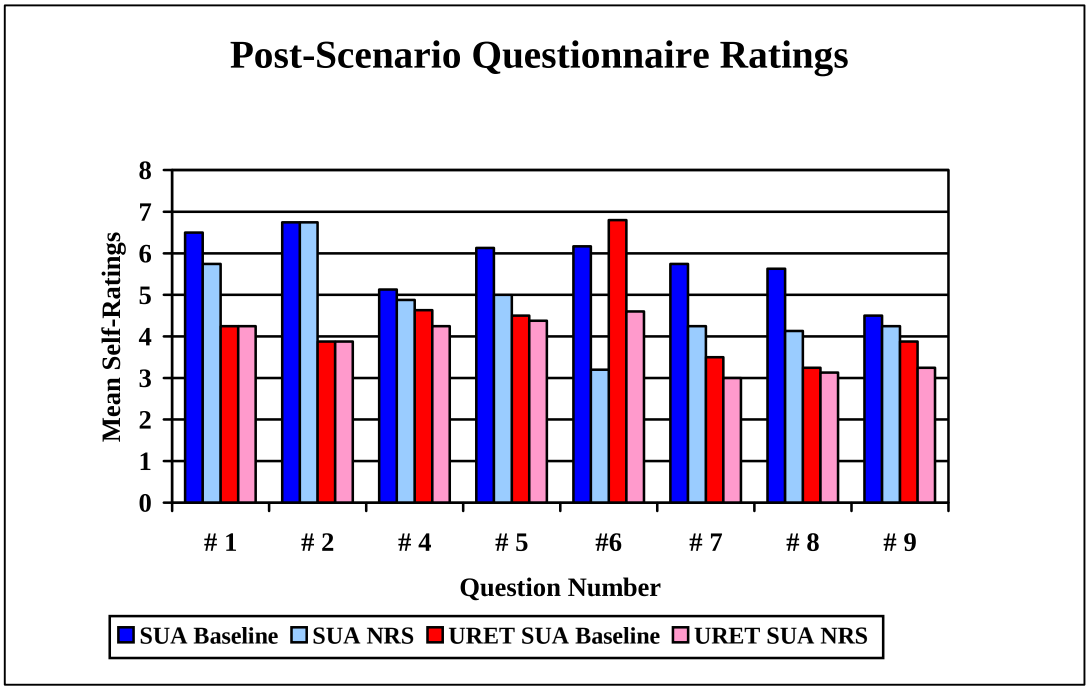

Figure 28. Post-scenario questionnaire ratings for the SUA scenarios.

3.6.4 Discussion

Overall, the availability of the NRS for rerouting aircraft around the active SUA had a significant impact on workload and controller efficiency, especially when working with flight strips.

3.7 Mixed Environment

3.7.1 TGF Output

From the automated TGF data collection system, we extracted the frequency of heading, speed, and/or altitude changes. There were no significant differences found among these variables. The means are depicted in Figure 29.

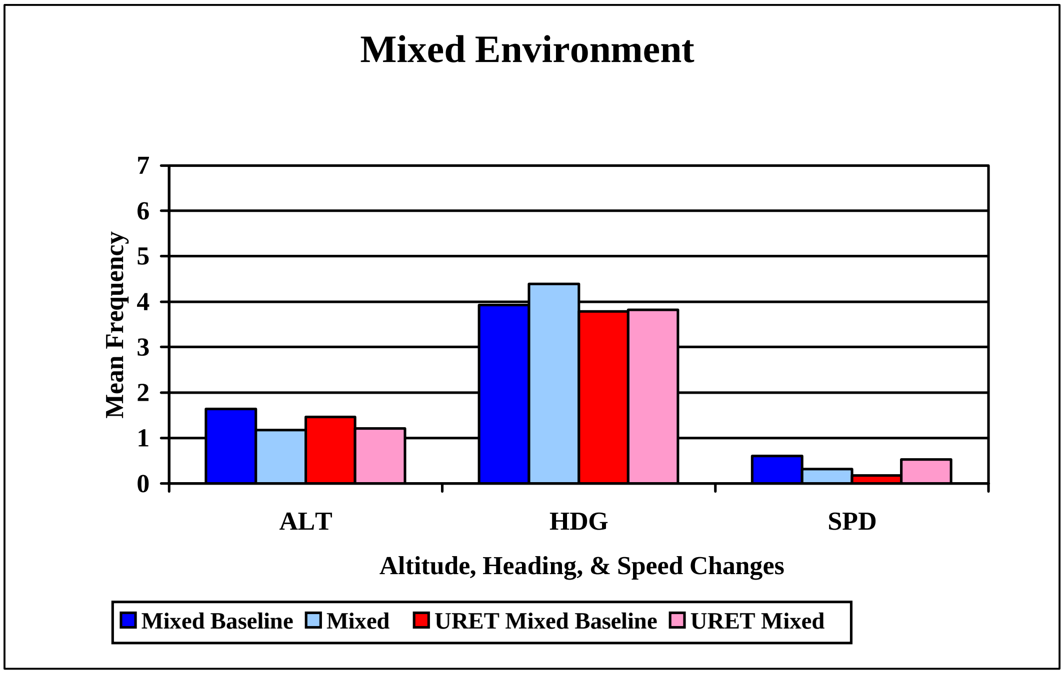

Figure 29. TGF output for the mixed environment scenarios.

For the efficiency indicators, there were no differences in the frequency of A/G communications, but there was a significant decrease in the duration of those communications in the mixed environment relative to the baseline scenario. The means for these two measures can be found in Figures 30 and 31, respectively.

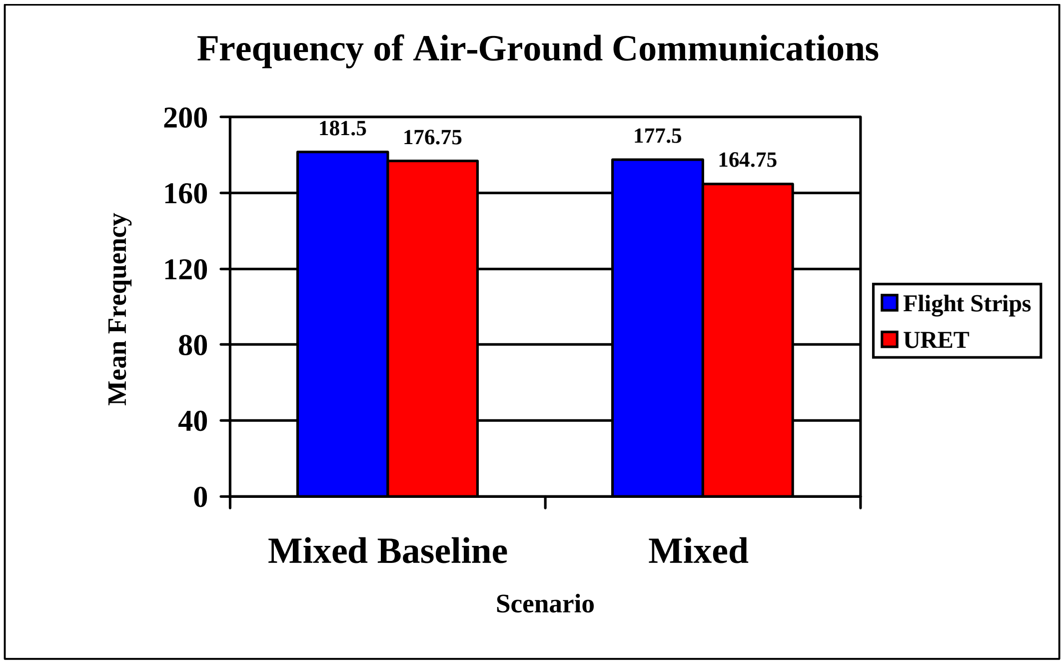

Figure 30. Frequency of A/G communications for the mixed environment scenarios.

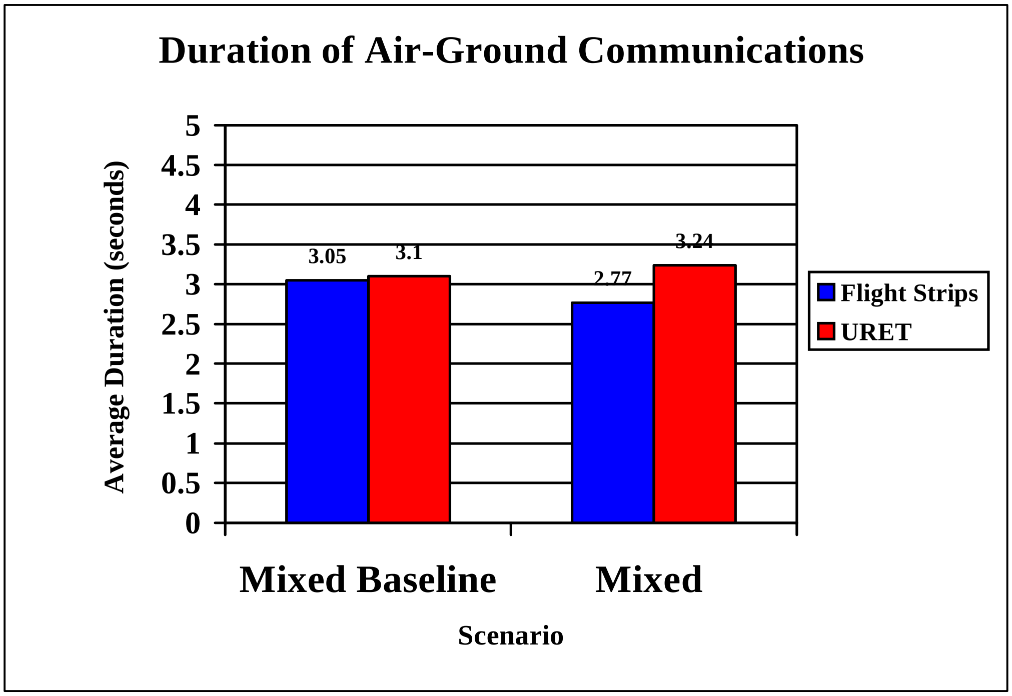

Figure 31. Average duration of each A/G communication for the mixed environment scenarios.

3.7.2 Subjective Workload

The average workload ratings are depicted in Figure 32. There were no significant differences found between the two scenarios.

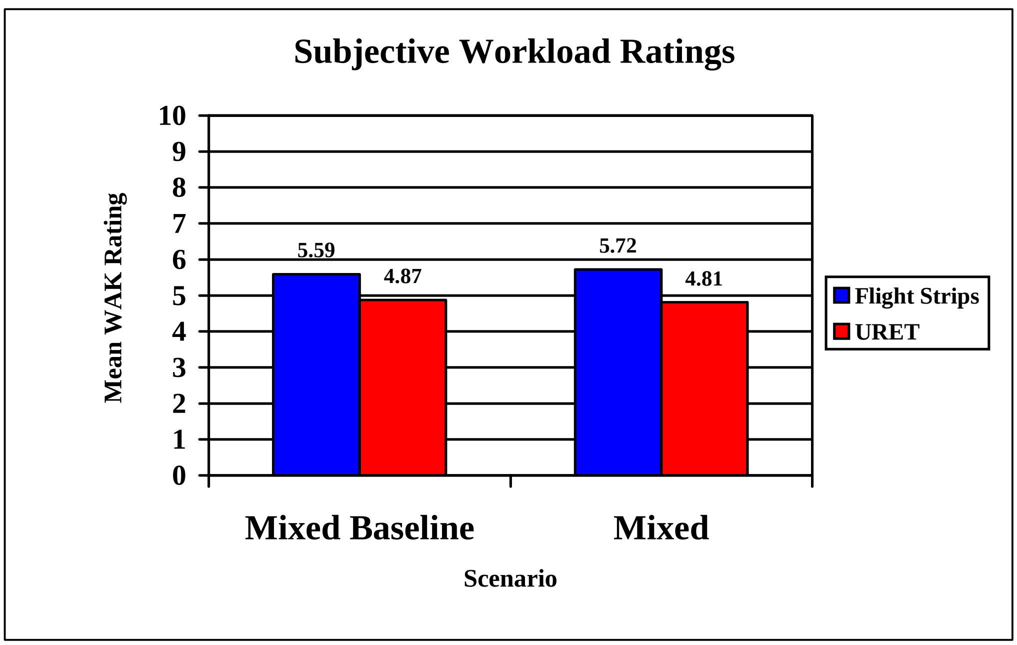

Figure 32. Average workload ratings for the mixed environment scenarios.

3.7.3

Post-Scenario Questionnaire

The mean ratings for the Post-Scenario Questionnaire items are depicted in Figure 33. On the strip side, participants had a significantly more difficult time resolving conflicts (item #8) in the mixed environment compared to the baseline. For the URET side, several significant differences were found. Participants rated the mixed environment scenario as significantly more workload intensive (items #1 and #5) than the baseline. Also, participants had a more difficult time detecting (item #7) and resolving (item #8) conflicts in the mixed environment than the baseline.

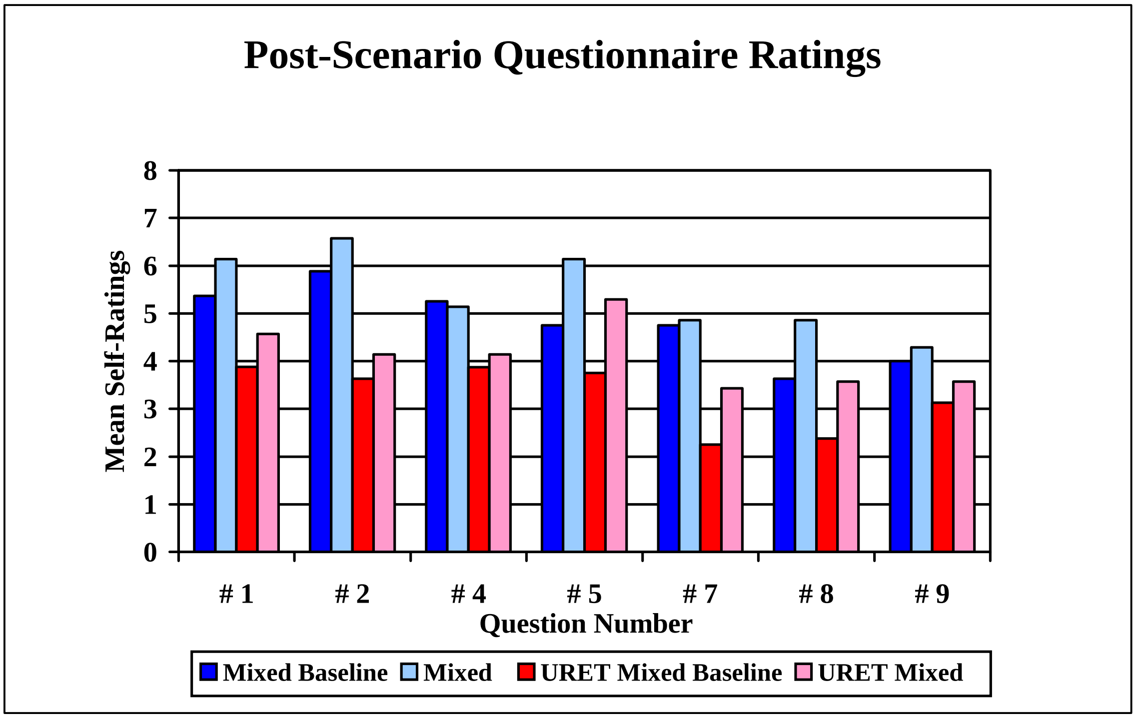

Figure 33. Post-scenario questionnaire ratings for the mixed environment scenarios.

3.7.4 Discussion

As expected, participants felt that the mixed environment scenario was the most difficult, regardless of whether or not URET was available. Participants had more difficulty detecting and resolving conflicts when non-equipped aircraft were allowed FL 350 and above.

3.8 Exit Questionnaire

The Exit Questionnaire consisted of both open-ended questions and items that required a rating. The Exit Questionnaire and responses to the open-ended items can be found in Appendices D and E, respectively. The responses to the rated questions are shown in Table 4. Overall, participants felt that the simulation was realistic and the simulation pilots performed very well. The consensus of the group was that URET had a very positive impact. They also felt that the feasibility of implementing both tactical RVSM and parallel RNAV routes was very high.

Table 4. Exit Questionnaire Mean Responses

Question	Scale Anchors		Mean
1. In general, how realistic was the simulation?	(1) Not very realistic	(10) Extremely realistic	5.62
2. To what extent did the WAK (workload assessment keypad) interfere with your performance?	(1) Not very much	(10) A great deal	1.25
3. Please circle the number that best describes overall how well the simulations-pilots performed during this simulation	(1) Extremely poor	(10) Extremely well	7.37
4. What type of impact did URET have on your performance?	(1) Very negative	(10) Very positive	9.88
5. Circle the number that best describes the feasibility of using parallel RNAV routes in the National Airspace System?	(1) Not very feasible	(10) Extremely feasible	7.25
7. Circle the number that best describes the feasibility of using tactical RVSM in the National Airspace System	(1) Not very feasible	(10) Extremely feasible	9.50
9. In the weather, SUA, and mixed environment scenarios, how useful was the navigational grid?	(1) Not very useful	(10) Extremely useful	9.25

4. General Discussion and Recommendations

The present study examined several concepts that are being considered for implementation in the high altitude strata in the very near future. The goal of this effort was to gather information from the participants and use their input to design a large-scale simulation to further investigate these concepts using site-specific airspace with various levels of traffic load. The culmination of the large-scale effort will be to provide input on how these concepts (NRS, tactical RVSM, and parallel RNAV routes) may be implemented within the constraints of the existing NAS architecture.

The recommendations for the large-scale follow-up simulation are separated by scenario and are described in the following sections.

4.1 Non-Restrictive Routing

With the exception of the baseline for this scenario (all aircraft on jet routes), all properly equipped aircraft (/E/F/G/R) were flying direct FL 350 and above in all subsequent scenarios. NRR needs to be examined under various traffic loads.

4.2 Tactical RVSM

If we implement only one of the concepts examined in this study, the use of RVSM for conflict resolution between properly equipped aircraft seems to be the most logical choice. There are no constraints such as altitude-for-direction, especially if implemented in an exclusionary airspace. The problem with tactical RVSM according to the participants was that tactical RVSM would not work in a mixed environment.

4.3 Parallel RNAV Routes

For the multi-ARTCC simulation to include parallel RNAV routes, the ARTCCs that are going to be simulated need to create a set of RNAV routes or a variety of RNAV routes that we can examine under various traffic loads. This way, we can determine which set is mutually beneficial. There is no reason to create a set of RNAV routes that help one ARTCC at the expense of increasing workload for the other.

4.4 NRS (Weather and SUA)

The NRS we used for our POC needs considerable expansion to be useful in a multi-ARTCC simulation. Rather than using lat/long clearances for deviating traffic, the participants preferred the use of the naming convention of the NRS. The NRS is a good idea; the problem is getting consensus on a naming convention and the level of detail. For the SUA scenarios, the research team recommends that coordination points be developed around existing SUAs. This would facilitate routing traffic around an active SUA, and if SUAs begin to be charted in high altitude airspace, pilots will have the ability to file around the SUA.

4.5 Mixed Environment

Participants had the most difficulty detecting and resolving conflicts in this condition. Overall, the participants felt that tactical RVSM would be difficult to implement in a mixed environment. It appears that a mixed vertical separation environment would have a moderate impact on workload and airspace complexity, especially transitioning aircraft from reduced vertical separation standards to conventional separation standards and vice versa.

5. General Recommendations

For the follow-up, we should introduce traffic load to the experiment and limit the concepts to be examined. We should also use URET-trained personnel from the ARTCCs in which we are testing (may not be possible as some do not have this tool yet). This will allow comparisons between the URET and non-URET scenarios.

Reference

Buckley, E. P., DeBaryshe, B. D., Hitchner, N., & Kohn, P. (1983). *Methods and measurements in real-time air traffic control system simulation* (DOT/FAA/CT-TN83/26). Atlantic City International Airport, NJ: DOT/FAA Technical Center.

Acronyms

ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCS	Air Traffic Control Specialist
API	Aircraft Proximity Index
ATDET	AT DSR Evolution Team
A/G	Air-To-Ground
RNAV	Area Navigation
CPC	Certified Professional Controller
CRD	Computer Readout Display
DFW	Dallas Fort Worth International Airport
D	Data-Side Controller
DSR	Display System Replacement
DSSC	DSR System Support Control
EI^{2}F	En Route Integration And Interoperability Facility
FIRS	FAA Interfacility And Radar Simulator
FAA	Federal Aviation Administration
FL	Flight Level
GPS	Global Positioning System
G/G	Ground-To-Ground
HAD	High Altitude Demonstration
HAT	High Altitude Test
HID	Host Interface Device
HITL	Human-In-The-Loop
ZID	Indianapolis ARTCC
LAN	Local Area Network
ZME	Memphis ARTCC
MIT	Miles In Trail
NAS	National Airspace System
NRS	Navigation Reference System
ZNY	New York Center
NRR	Non-Restrictive Routing
POC	Proof of Concept
R	Radar-Side Controller
RVSM	Reduced Vertical Separation Minima
RNP	Required Navigation Performance
RDHFL.	Research Development & Human Factors Laboratory
SUA	Special Use Airspace
SME	Subject Matter Expert
TGF	Target Generation Facility
URET	User Request Evaluation Tool
VSCS	Voice Switching And Control System
WAK	Workload Assessment Keypad

WAK Workload Assessment Keypad

Appendix A

Participant Consent Form

HIGH ALTITUDE DEMONSTRATION
PROOF OF CONCEPT SIMULATION
PARTICIPANT CONSENT FORM

I, ______________________________, understand that the Federal Aviation Administration sponsors this study, entitled "The High altitude demonstration (HAD): proof of concept".

Nature and Purpose:
I will volunteer as a participant in the project above. I understand the purpose of this effort is to examine the high altitude concept. The results and conclusions obtained in this initial examination will be used to drive a major follow-up simulation that will include several ARTCCs.

Experimental Procedures:
The eight participants will be CPCs from several different ARTCCs. Generic airspace (two sectors from Memphis ARTCC-ZME) will be used in this simulation. None of the participants will be from ZME.

Participants will be exposed to several new concepts and procedures (Tactical RVSM, Parallel RNAV routes, and a navigational reference system in an exclusionary airspace (FL 350-410) where properly equipped aircraft are flying non-restrictive routes). An automated data collection system will record important simulation events and produce a set of system effectiveness measures, which include safety, capacity, and efficiency. In addition on-line measures of controller workload will be collected throughout the scenarios. After each scenario, controllers will also complete questionnaires to evaluate the concept and provide feedback on the development of procedures.

Discomforts and Risks:
I understand that I will not be exposed to any foreseeable risks or intrusive measurement techniques.

Benefits:
I understand that the only benefit to me is that I will have the opportunity to provide feedback and valuable insight on the feasibility of this high altitude concept to the research team conducting the simulation.

Participant Responsibilities:
During the experiment it will be my responsibility to control air traffic and regard the simulated air traffic as if it were live traffic. I will answer any questions asked during the experiment to the best of my abilities. I will not discuss the content of the experiment with anyone until the completion of the experiment. I will complete a background questionnaire, a post run questionnaire at the end of each scenario, and a post-simulation questionnaire at the end of simulation. I will participate in debriefs at the end of each scenario, and a post-simulation debrief.

Participants Assurances:
I understand that my participation in this study is completely voluntary. Jerry Hadley has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that Jerry Hadley will be available to answer any questions concerning procedures throughout this study. I understand that if new findings develop during the course of this research that may relate to my decision to continue to participation, I will be informed.

I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study are strictly confidential, and that I will not be identifiable by name or description in any reports or publications about this study. Photographs and audio recordings are for use within the William J. Hughes FAA Technical Center (WJHTC) only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal to the WJHTC without my written permission.

I understand that I can withdraw from the study at any time without penalty or loss of benefits to which I may be entitled. I also understand that the researcher or sponsor of this study may terminate my participation if he or she feels this to be in my best interest.

If I have questions about this study or need to report any adverse affects from the research procedures I will contact Jerry Hadley (609) 485-7920

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Research Participant: _________________________ ___ Date: _____________

Research Director: ____________________________ Date: ______________

Witness: ____ Date: ______________

Appendix B

Background Information Form and Instructions

Instructions:
This form is to be completed by all controller participants. The form requests general background information.

Your name will not be listed or appear in any reports in order to insure your anonymity and to encourage unbiased reporting. Findings will be reported generically, e.g., Controller A, B, C, etc.

Background Information Form

Controller ID: ___________

Date: ______________

1. How long have you actively controlled traffic for the FAA?
   Years: _______ Months: _______

2. How many of the past 12 months have you actively controlled traffic in your facility?
   Months: _______

3. How many years have you been a CPC?

   Years: _______ Months: _______ Area: ______

4. How many years of ARTCC experience as a CPC do you have?

   Years: _______ Months: _______ Area: ______

5. List the FAA facilities you have worked at starting with your current assignment?

APPENDIX C

POST-SCENARIO QUESTIONNAIRE

High Altitude Demonstration

January 28 – February 8, 2002
Controller Post-Run Questionnaire

Run Number:	____________	Scenario:	TC Use Only: ____________
Participant ID:	____________	Position:	____________
Date:	____________		

Rate your overall mental workload during this run. (Mental workload refers to planning, coordination, etc.).

1	2	3	4	5	6	7	8
Very Low				Moderate			Very High

Rate your overall physical workload during this run. (Physical workload refers to data entry, flight strip manipulation, etc.)

1	2	3	4	5	6	7	8
Very Low				Moderate			Very High

A. Were there any tasks that you would normally perform when controlling traffic that you were unable to perform during this particular scenario? (Check one) Yes ☐ No ☐

B. If you answered "Yes" to part A, please list the tasks you were unable to complete.

____

____

Rate the workload you experienced with ground-to-air communications during this run.

1	2	3	4	5	6	7	8
Very Low				Moderate			Very High

Comments:____

____

Rate the workload you experienced with controlling aircraft FL 350 and above during this run.

1	2	3	4	5	6	7	8
Very Low				Moderate			Very High

Comments:____

____

If weather or SUA was present, rate the workload associated with issuing lat/long clearances (e.g., readback errors, increased A/G communications) for deviating aircraft.

1	2	3	4	5	6	7	8

Negative impact No impact Positive impact

Please explain.

____

____

Rate the level of difficulty you experienced with detecting conflicts during this run.

1	2	3	4	5	6	7	8

Not difficult Somewhat difficult Very difficult

Comments:____________________________________

____

Rate the level of difficulty you experienced with resolving conflicts during this run.

1	2	3	4	5	6	7	8

Not difficult Somewhat difficult Very difficult

Comments:____________________________________

____

Rate the level of difficulty you experienced with accepting and/or handing off aircraft at random points on your sector boundaries during this run.

1	2	3	4	5	6	7	8

Not difficult Somewhat difficult Very difficult

Comments:____________________________________

____

If non-restrictive routing was in effect, rate the impact of implementing MIT restrictions.

1	2	3	4	5	6	7	8

Negative impact No impact Positive impact

Please explain.

____

____

Parallel RNAV Routes

Rate the workload you experienced with using parallel RNAV routes during this run.

1 2 3 4 5 6 7 8

Very Low Moderate Very High

Comments:____

____

Rate the effectiveness of using parallel RNAV routes to counteract overtake situations.

1 2 3 4 5 6 7 8

Not effective Somewhat effective Very effective

Comments:____

____

Rate the impact of parallel RNAV routes on crossing traffic situations.

1 2 3 4 5 6 7 8

Negative impact No impact Positive impact

Please explain:

____

____

Did parallel RNAV routing influence your separation decisions (e.g., issued altitude changes more than vectors)?

Yes ________ No _________

If yes, please explain.

____

____

Did parallel RNAV routes provide a benefit in controlling traffic during this scenario?

Yes ☐ Please explain No ☐ Please explain

____

Was the 8 NM separation an additional workload factor for radar monitoring?

Yes ________ No _________

If no, please explain.

____

____

If 8 NM separation was not adequate, what separation would you recommend, and why?

____
____
____

Should parallel RNAV routing be used for 'Fast Lane-Slow Lane' applications?
Yes ________ No _________

If no, please explain.

____
____

RVSM

Rate the effectiveness of tactical RVSM for separating aircraft during this last run.

1	2	3	4	5	6	7	8
Not effective		Somewhat effective				Very effective	

Comments:____

What effect did RVSM have on the overall complexity of the traffic during this run?

1	2	3	4	5	6	7	8
Reduced complexity		No effect on complexity				Increased complexity	

Comments:____

Rate the workload you experienced with non-equipped RVSM aircraft during this run.

1	2	3	4	5	6	7	8
Very Low				Moderate			Very High

Comments:____

Did RVSM change the way you considered separating aircraft (e.g., altitude changes more than vectors) during this last run?

Yes ________ No _________

If yes, please explain.

Did having RVSM available affect the timing of your control actions?

Yes ________ No _________

If yes, please explain.

With RVSM during this last run, I took…

fewer ________ the same number ________ more _________

…aircraft off course than in the non-RVSM scenarios.

Comments:

Grid Navigation

Check Which Was Present In Last Scenario: Weather ____ SUA ____

Rate the effectiveness of grid navigation for separating aircraft during this last run.

1 2 3 4 5 6 7 8

Not effective Somewhat effective Very effective

Comments:____

____

Please indicate your preference for issuing clearances.

Named grid points ________ Lat/Longs ________

Comments:

____

____

Please indicate your preference for resolving conflicts.

Named grid points ________ Lat/Longs ________

Comments:

____

____

Rate the level of difficulty experienced with using the grid points to reroute traffic/handle deviating aircraft as opposed to using conventional lat/long clearances.

1 2 3 4 5 6 7 8

Not difficult Somewhat difficult Very difficult

Comments:____

____

Rate the impact of weather and/or SUA on parallel RNAV routing during this last run.

1 2 3 4 5 6 7 8

Negative impact No impact Positive impact

Please explain:

____

____

Rate the impact of weather and/or SUA on grid navigation during this last run.

1 2 3 4 5 6 7 8

Negative impact No impact Positive impact

Please explain:

APPENDIX D

HIGH ALTITUDE DEMONSTRATION

EXIT QUESTIONNAIRE

Participant Code Date

INSTRUCTIONS

The purpose of this questionnaire is to obtain feedback from you concerning different aspects of the experiment. This information will be used to improve our simulation in the future. In addition to your ratings, you will be asked to make comments on some of the questions. Even if your ratings are other than favorable, you may wish to make further comments. If you feel you have any helpful ideas regarding this experiment, we would like to hear from you. So that your identity can remain anonymous, your actual name should not be written on this form. Instead, your data will be identified by a participant code known only to yourself and the experimenters.

1. In general, how realistic was the simulation?

Not very realistic	1	2	3	4	5	6	7	8	9	10	Extremely realistic

Comments____

____

____

____

2. To what extent did the WAK (workload assessment keypad) interfere with your performance?

Not very much	1	2	3	4	5	6	7	8	9	10	A great deal

Comments____

____

3. Please circle the number that best describes overall how well the simulation-pilots performed during this simulation.

extremely poor	1	2	3	4	5	6	7	8	9	10	extremely well

Comments____

4. What type of impact did URET have on your performance? Why?

very negative	1	2	3	4	5	6	7	8	9	10	very positive

Comments____

____

____

5. Circle the number that best describes the feasibility of using parallel RNAV routes (separated by 8 miles) in the National Airspace System (NAS).

Not very feasible	1	2	3	4	5	6	7	8	9	10	extremely feasible

Comments____

____

____

6. What do you see as the benefits of this concept (RNAV routes)?

Comments____

____

____

7. Circle the number that best describes the feasibility of tactical RVSM in the National Airspace System (NAS).

Not very feasible	1	2	3	4	5	6	7	8	9	10	extremely feasible

Comments____

____

____

8. What do you see as the benefits of this concept (tactical RVSM)?

Comments____

____

____

9. In the Weather, SUA, and Mixed environment scenarios, how useful was the navigational grid?

Not very useful	1	2	3	4	5	6	7	8	9	10	extremely useful

Comments____

____

____

10. If you were selected to be a Subject Matter Expert in the follow-up to this study, what changes/additions would you make to the Navigational Grid? and why?
Comments____

____

____

11. Describe any situation or conditions where tactical RVSM, parallel RNAV routes, and/or a grid navigational system would be useful in your facility.
Comments____

____

____

APPENDIX E

EXIT QUESTIONNAIRE CONTENT SUMMARY

		Participant 1
Question Number	Rating	Comment
1	6	As usual in a DYSIM environment you loose many realistic problems. No VSCS, no rough RIDE problems, lost time is problem pilots, etc. I do believe, however, what was set out to be proven was accomplished successfully.
2	1	no comment
3	9	Much better than real life pilots
4	10	These problems being designed to be busy was accomplished. The use of URET is the BEST way to move this number of aircraft.
5	10	Only as long as the pilots will be responsible for separation. 8 miles will not work for drifting aircraft. The amount of time to take action is too limited.
6	-	It's great with multiple tracks (two each way with fast and slow track) Check ZMPs "FHARTS" Proposal. The concept will only work if all aircraft are capable to do it. Otherwise the workload would be too great to sort them.
7	10	As long as all aircraft can do this. If you need a past fix you don't have time to see if both are in compliance.
8	-	A fast safe way to move more aircraft safely. A small fix allows more time to keep your eyes moving for the next conflict. The benefit to the user would greatly be improved and safely.
9	10	An excellent way to move aircraft from one point to another, much faster than lat/long or range/bearing
10	-	Make more than one grid line; I would want 4 or 5 north/south and east/west. Let's see how it could really be used.
11	-	There's too many.

		Participant 2
Ques. #	Rating	Comment
1	3	No coordination, No VSCS, "crappy" communication system. We could have been in the "real" lab! Also no A-SIDE sometimes hurt us.
2	2	
3	8	Much better than WCG
4	10	You could not run these problems efficiently with out it. D-sides could not possibly keep up with all the strip marking
5	4	A fast lane/slow lane for situations would be nice.
6	-	Resolving overtakes as long as the next center can handle two aircraft side by side until speeds take effect.
7	10	Get those morons (NWA) to equip. their A/C (DC9s) with the right stuff and lets do it. A mixed environment would be potentially dangerous and unacceptable.
8	-	Reduced off-course vectors for traffic. Simple resolution of most conflictions.
9	9	It was great, however, in weather I might still "lock" the A/C on headings.
10	-	The grid was great, however, I would leave it to industrial centers/areas as to appending it. In addition it would have to be with named (IE MEUI, STF04) POINTS and NOT via LAT/LONG clearances as all they do is increase workload.
11	-	RSVM - MSP Landers (NWA) crossing T60 @ FL 360 thus no vectoring. IIRNAV- fastlane/slowlane for EWR/JFK chore point routes. Grid- to increase departure tracks on Chicago Metro Airports.

		Participant 3
Ques. #	Rating	Comment
1	7	The weather system was more like a SUA
2	1	no comment
3	8	no comment
4	9	Very useful tool - data entry is easier and conflict probe allows attention to stay focused on traffic and issuing clearances.
5	10	They will work as long as weather is not a factor.
6	-	Allowing A/C to reach filed ALT when behind slower traffic.
7	8	RVSM will work better if all A/C are equipped. It is still useful to separate A/C, but not a first option in a mixed environment.
8	-	The biggest use will be on crossing traffic; or A/C heading the same general direction, but on the wrong sides of each other.
9	9	In this scenario where the weather did not move it worked. In actual work, the pilots go different routes thru the weather around a SUA it would be very useful.
10	-	I would drop a couple of the ME points, only because they were close to the STF points.
11	-	Tactical RVSM and parallel RNAV would be useful for outbound (EAST) traffic. All traffic is sent out over two or three fixes. The grid system would allow the users to file around (closer to) a SUA that is used most days

		Participant 4
Ques. #	Rating	Comment
1	7	Problems were too busy to concentrate on effective control. Reaction was the mail mode instead of control.
2	2	It seemed to be very subjective.
3	6	I don't really understand what tools they had work with to criticize.
4	10	URET is a must for HAD! URET makes everything come together with the 'D' and 'R' side controller. It identifies the hidden problems with HAD routes.
5	10	no comment
6	-	Slow movers can be easily moved aside for the fast guys
7	8	We should do all or nothing on this!
8	-	In a sterilized environment it is safe and easy. Mixed environment, it's dangerous and would cause many system errors.
9	10	Grid would be great if we would just do it.
10	-	I would use the SNARS system. It is world wide and easy to understand.
11	-	All there are/would be extremely useful - please read the ZLC HAT study. It has all the info you could want in this subject.

		Participant 5
Ques. #	Rating	Comment
1	5	Lack of Landline communications really minimizes workload. A few "were getting chop" prompts would be good. On weather problems some of work would've been absorbed by surrounding sections. This problem was too busy to effectively try tools.
2	1	no comment
3	9	no comment
4	10	D-side with URET was more help in solving problems, watching for traffic, SUAs, etc. Radar side seemed easier with URET. URET should be fielded everywhere soon.
5	7	If surrounding facilities could loosen MIT restrictions and not treat the parallel routes as one route for this, they could be very beneficial. For certain overtake situations they could be valuable. As everyday routes one would say a 3-4 rating as to restrictive. Mixed environment decreases the benefit of using this.
6	-	See number 5. Additionally in narrow corridors they may help and set up dual inbound routes to airports could be beneficial.

7	10	RVSM decreased complexity tremendously by giving controller a good option vs. vectoring especially when moving altitude 2,000-4,000 feet would've been difficult for traffic. In a non-exclusionary environment the mental workload was too much to make this an effective option and end up not being utilized due to the added complexity.
8	-	See number 7. Instead of having to turn 2-3 aircraft or struggle with 2,000-4,000 feet decent/climb, it provided a single solution to complex situations.
9	9	Weather 9-10, SUA 9-10, mixed environment 3-4. (mixed due to too much effort to figure out who could and couldn't fly points so used headings more. Also naming convention so you can just have pronounceable name as "stef 1" in simulation is very important.
10	-	The simulation needed more than one grid line to truly simulate option. The angles were often too sharp to be effective in simulation. More waypoints and charting/mapping is important to evaluate.
11	-	RVSM - many is crossing traffic, complete situations, overtakes, MIT (could put aircraft needing s turns at RVSM altitude so as not effect en route aircraft. P-RNAV - Playbook routes for different destinations vs everybody over 1 point, MIT (east/slow or 2 streams vs. 1 for airport hundreds/thousands miles away.) Grid - WX, SUA, points for aircraft to file for winds, MIT when putting 2-3 streams into 1., slow divergences.

		Participant 6
Ques. #	Rating	Comment
1	7	Probably too many aircraft. No coordination between sectors, no discussion of rides. Pilots would 'check on' the frequency before handoffs are taken.
2	1	
3	3	I realize it may seem boring for them, but they should stick with standard phraseology.
4	10	Anything that rids us of strips is a positive improvement. The red vs. yellow alerts is a fantastic tool/enhancement.
5	1	I believe it could be used in some parts of the U.S. But, let's face reality; no center east of the Mississippi has the room to use these routes.
6	-	I don't
7	10	If ALL aircraft are participants, AND it is used only for conflict resolution, not solid/ permanent altitude assignment. Excellent tool for short-term separation.
8	-	See number 7.
9	8	Using fixes around a SUA makes perfect sense. For WX, NO. Pilots can't be locked down to a particular FIX/point in space, during WX.
10	-	I would suggest dropping the MEOI, MEOZ, etc… and concentrate on SUA avoidance grid fixes. With DSR, it's easy to fix flight plans without "6,7,10s" also, I see no reasonable method of 'naming' these fixes. Or where would you place them? Publish on GPS? Again I don't think the east coast has the room for more fixes.
11	-	RVSM would be an incredible improvement for both the pilots and the controllers. It is hard to get a plane up 4,000 feet to re-establish separation. However, 1,000 or 3,000 feet would make a big difference. Also many A/C get vectored about each other that could have been left on course and only moved 1,000 feet up or down.

		Participant 7
Ques. #	Rating	Comment
1	5	Unrealistic amount of traffic, aircraft-types unrealistic (B737 with an overtake on a B727), sectors handing off 7 miles with a 40 knot overtake; other than that it was pretty realistic.
2	1	Paylov's Dog response; once you got used to it, it was fine.
3	7	Some problems with aircraft, making wrong turns.
4	10	The FAA should be ashamed of themselves for not having URET in every aircraft NOW!
5	8	Good in certain situations; no help with crossing traffic but good for overtakes and certain RNAV routes for certain destination airports.
6	-	See above.
7	10	A 10 only in exclusive airspace. It is a 1 if used in a mixed environment, too much work involved if trying to use RVSM with a lot of non-RVSM aircraft.

8	-	No brainer - use 1,000 feet for crossing traffic instead of turning aircraft off their route. Also could be used when climbing or descending. (ie: bad rides up or down off of airports.
9	10	Anytime a controller can use RNAV instead of headings, it would benefit both pilots and controllers. Might help to do away with aircraft on poor headings for long periods. Would save airlines on fuel costs.
10	-	Need more grid points. When there is only one line of grid point there is a somewhat limited use, especially with WX and SUAs. Give controllers more options.
11	-	Already use as Oceanic transition, (RVSM) in my area. Could use when crossing PDX and SEA arrivals instead of changing aircrafts altitude 4,000 feet. RNAV routes would help both putting aircraft a certain RNAV routes for certain airports. Grid system, see previous answers. RNAV points around SUAs would help our ARTCC now.

		Participant 8
Ques. #	Rating	Comment
1	5	After working a problem on the URET side, you knew on the strip side what airplanes were going to slip by. In the live environment those aircraft would have been handled differently.
2	1	No interface at all.
3	9	They worked very well and handled a lot of inputs.
4	10	Every center should have URET - It is so valuable it should not be cost driven. ONE FAA!!!
5	8	Good idea, tough around WX or SUA, does not work.
6	-	Helps sort traffics without having to watch and coordinate vectors.
7	10	It works extremely well in an exclusionary environment. It will not work in a mixed environment.
8	-	Reduces vectors, workload and coordinator
9	9	Grid system works well, get rid of lat. and longs.
10	-	I would add more points for Grid navigation.
11	-	Grid system works wonders around SUA. It would work well around Approach airspace also.